

2nd ed 1750
revised & enlarged

Al Swett

RADIO *for* EVERYBODY



BASEBALL games, boxing contests, banquets, political conventions, speeches by our great leaders, theatrical plays, concerts, lectures, news of the day, time signals, market and crop reports, weather forecasts and storm warnings, stock quotations, jazz selections and dance music, songs, instrumental solos, instructive as well as entertaining talks—these are some of the good things placed in the air by the broadcasting stations of today, and made available to anyone with a radio receiving set. To the great army of broadcasters and radio entertainers—the rock on which popular radio is founded—this work is duly dedicated.

RADIO *for* EVERYBODY

A popular guide to the fascinating subject of radio communication in general, and the practical reception of radio broadcasting programs and news features in particular, for the layman who wants to apply radio for his pleasure and profit without going into the special theories and the involved intricacies of the art.

By AUSTIN C. LESCARBOURA
Managing Editor, Scientific American

Entirely Rewritten and Enlarged Edition

SECOND IMPRESSION

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PREFACE

THIS little volume has grown up with radio telephone broadcasting. It was first conceived during the closing days of 1921, when one of the editors of the SCIENTIFIC AMERICAN was invited to speak for the small radio audience then served by the only radio broadcasting station in the New York metropolitan district. It did not require much foresight or much stretching of the imagination to visualize the promising future of this remarkable means of disseminating news, talks and music, and accordingly the editorial staff of our journal decided then and there to devote considerable time and thought to radio.

An old-time wireless amateur, it became my lot to pick up the thread of wireless or radio from where I had left off back in 1911, when the vacuum tube was just beginning to be talked about, and a few of the more fortunate amateurs boasted of their possession of these wonderful electric lamps.

The task was far from an unpleasant one. I spent considerable time studying the reaction of the general public to radio broadcasting. I installed one of the first broadcast receivers in my home in order to study this new art and its practical application at first hand. Indeed, the manu-

script for the first edition, as well as for all subsequent editions and revisions, was written on the very table on which I have my radio receiving set; and as urgent as this work has been in order to have it appear within the shortest possible time, to be of greatest service to its readers, I am free to confess that I have often been unable to resist listening-in on the radio entertainment, sometimes to the clicking accompaniment of my typewriter.

Then, too, the hundreds and the thousands of inquiries which have poured into the editorial rooms of the SCIENTIFIC AMERICAN have proved an invaluable guide, not to forget the numerous conversations with persons met in and out of business. And even with the considerable amount of editorial space which has been devoted to radio developments in the SCIENTIFIC AMERICAN during the rapid progress of popularized radio, it has been found utterly impossible to keep up with the demand for radio information. We have covered only the outstanding features in our magazine columns, having no space for details and working data. Hence the overflow of radio material has been diverted to this little book wherein it can be treated at length without regard to space limitations.

The first edition of this work bore the date of April 10, 1922. It was soon exhausted, and several subsequent reprintings were necessary to supply the demand. But during the months following the appearance of the several editions, many specu-

lar developments took place in radio. As might well be expected, an art so young and so intricate as radio broadcasting was replete with rough spots, so to speak, which had to be removed or polished as time went on. Then, too, highly inventive minds have been at work in the radio field, and numerous laboratory ideas of yesterday have reached the commercial, everyday application of today. Therefore, much of the material appearing in the earlier editions of this work has become obsolete. No other art has shown such progress and so many and startling changes.

So, "Radio for Everybody," begun with the birth of radio broadcasting, has grown right along. There have been eight revised editions of the first work, until finally these revisions became so intricate and involved as to exceed the mechanical limitations of printing. Frankly, the last edition was so revised and patched, as it had to be to bring it up to date, as to resemble the familiar crazy quilt with its all-but-infinite variety of different pieces of goods.

The present edition, therefore, represents a *new* manuscript from start to finish, so as to meet present-day radio broadcasting conditions. *This is a new book*, although the old title and the original idea have been retained.

Perhaps it is well here to repeat in part what I said in the preface to the previous editions:

Radio broadcasting is and must remain a radio proposition. It calls for radio apparatus and some

knowledge of radio communication as a whole, just as the owner of an automobile should have a general knowledge of the mechanism involved, even though it is unnecessary to delve deeply into the minute construction of the machine and into the expansive field of automotive engineering. What is required is practical and helpful information about the mechanism with which the desired results are obtained.

This work has been written with that very thought in mind. It has been built up for the layman who wants to enjoy radio concerts and talks to the utmost, but who does not wish to take the time and the trouble to dig deep into the intricacies of radio engineering. It aims to give the essential, practical information, with a minimum of theory and a total absence of mathematics. It should present much of interest to the beginner who is going to build or buy a radio set; it can teach not a few things to the radio devotee who possesses a radio receiving set and wishes to learn more about his set and better sets; it may possibly have something of interest for the radio amateur who has progressed pretty far along in this art, although I am frank to say that for the dyed-in-the-wool radio amateur and radio engineer, this book is no doubt too elementary.

I take this opportunity once more of thanking the radio fraternity as a whole for its wholehearted co-operation. Several of the leading radio manufacturers have been more than kind in ex-

tending every possible facility to me in the preparation of this new edition, not only by supplying invaluable data, but also their products so that I might obtain much of my data from first-hand experience. Then, too, I desire to thank the reader, whose very interest in radio has spurred me on to keep in touch with radio progress and, in that manner, partake of the pleasures of this, the most fascinating pastime of all ages.

Finally, in reading the following pages of this little volume, friend reader, I sincerely hope you will obtain as much enjoyment and knowledge from the practical application of the facts presented as I have gained in gathering the material and writing it for you.

THE AUTHOR.

Croton-on-Hudson,
July 30, 1924.

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CHAPTER I.

BROADCASTING, OR RADIO PROGRAMS IN THE MAKING

“ONE, two, three, four, five. Hello, Fort Wood. One, two, three, four, five. Hello, Fort Wood. Here’s some music for you.” And a moment later came the strains of the Anvil Chorus from the opera *Il Trovatore*, played for about the fiftieth time that day by the hardworking cylinder-type phonograph of rather questionable musical attainments.

That was the radio broadcasting program of 1909. As a matter of fact, it was not intended as a broadcast feature. Back in those days we firmly believed that radio telephony might be used as a rapid means of radio communication, especially for military operations. Of course we appreciated the fact that the radio telephone conversation could be intercepted by anyone, but it never occurred to us that this means of communication might be employed for nation-wide entertainment. Little did we dream that the very weakness of radio telephone—its total lack of secrecy—would some day become its greatest asset.

WITH SPUTTERING ARC AND BAKED MICROPHONE

No beautiful broadcasting studio was available in those pioneer days for our radio telephone efforts. Instead, we were working in the icy-cold room of the wireless station located behind the big disappearing guns of Fort Hancock, amid the barren wastes of that stick of land known as Sandy Hook, in Lower New York Bay. No neat and almost invisible microphone was presented for our vocal talent; instead, we were shouting into a long fibre horn, as we stood before a large table littered with apparatus and fitted with a tall back covered with delicate electric meters and fuses and switches. Immediately before us were ten tall copper cylinders, filled with water, and resembling nothing so much as the pipes of an organ. Below each copper cylinder was a large carbon button, all but pressing against the bottom of its respective cylinder. Between the cylinder and the carbon button played an unsteady electric arc, sputtering and flickering all the while. The ten arc units were arranged in two banks of five arcs each, while each bank was controlled by a large upright handle so that all five arcs of the bank might be struck at once. Once the arcs were "struck" or formed by touching and then separating the copper and carbon members, it was necessary to adjust the gap of the arc so as to get the utmost stability, thus producing the uniform radio waves on which to impress the telephone message or music, as the case might be. And here was the annoying feature; for no sooner did we get one of the arcs fairly constant and turned our efforts to the next unruly arc, than the first arc would go off on a rampage, electrically speaking.

Given exceptional luck, it was possible at times to get all ten arcs on their best behavior. This happy

state of affairs was confirmed by the passive state of one of the electrical instruments, known as the oscillating circuit milli-ammeter.

The next step was to prepare to talk. The microphone, or device which translates sound waves into their electrical equivalent, was in this case a flat cartridge with two contact buttons. It was slipped into a holder over which was placed the long fibre horn. Then, if the arcs were still behaving themselves, we were ready to talk—or shout, to be more precise in our description.

All of which was for the purpose of convincing the U. S. Army Signal Corps that here was a wireless telephone or radio telephone that would work—on occasion. We were endeavoring to put some radio sounds into the air at Fort Hancock, and trying to get those same sounds out of the air again at Fort Wood, eighteen miles away as the crow flies. The Fort Wood receiving station was by no means of fortunate location, so far as radio is concerned, because it nestled right at the very feet of the bronze lady known as the Statue of Liberty. Despite the application of a five kilowatt input at the transmitter—just ten times as much energy as the usual present-day broadcasting station—we could only hope to get through to our anxious listeners in once in a great while.

The output from our arc transmitter was passed in large measure through the cartridge microphone, with the consequence that the loose carbon grains of the microphone were soon baked into a solid mass by the heat developed. All the while we were shouting into the horn or playing the phonograph, it was necessary to rap the microphone holder with a screw-driver or any other handy tool so as to break up the rapidly baking carbon grains in order that the sound waves could be accurately translated into variations of the

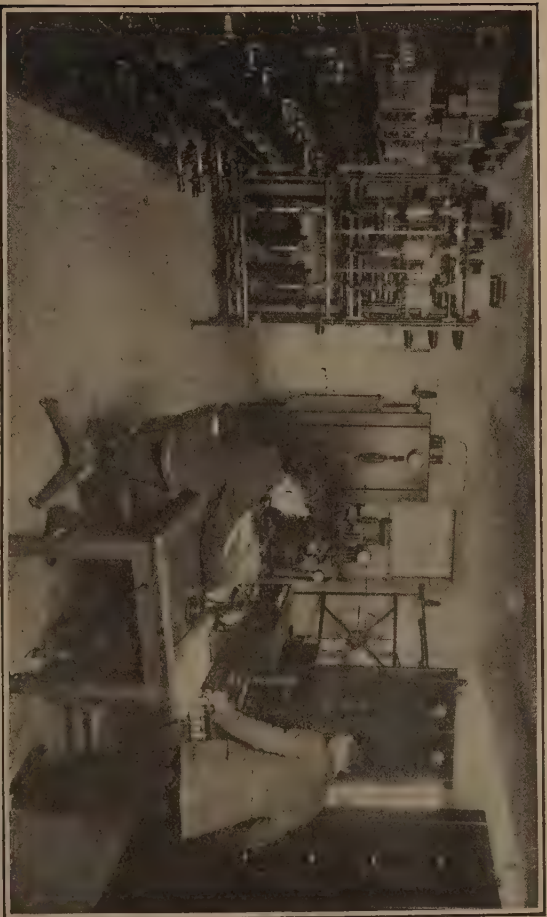
out-going radio waves. At the end of several minutes of more or less uncertain transmission, the microphone would be baked solid and a new one would be necessary.

That, in brief, was the 1909 model of radio broadcasting station. The author, who participated in those early radio telephone attempts, had no illusions about the possibilities of radio telephony. To him, as well as to others engaged in that early experimental work, the technical obstacles were such as to seem insurmountable. As a laboratory experiment, the radio telephone was indeed interesting; but as an everyday convenience, it seemed doomed to ignominious failure, even at the very start.

AND ALONG CAME THE VACUUM TUBE

In the annals of a young art like wireless communication, fifteen years is an age. Even as we were experimenting with our crude arc transmitter, Lee DeForest, a wireless experimenter and inventor already well known at that time, was at work on his audion—a modified form of electric bulb in which are placed two elements in addition to the usual filament, one of these a metallic plate or cylinder known as the “plate,” and the other a lattice-like structure known as the “grid.”

Four years after our disheartening efforts at wireless telephoning, a young college student, Edwin H. Armstrong, was delving deeply into the intricacies of the audion or vacuum tube, and evolving new and wonderfully efficient circuits for radio transmission and reception. That was in 1913. Two years later, the American Telephone & Telegraph Company startled the world by assembling a large battery of vacuum tubes for the purpose of generating sufficient radio



The business end of the broadcasting station, showing the control board at the left, together with the tube rack, the operator at the table in the center foreground, and the radio engineer studying the oscillograph of the radio programs after they have been translated into radio waves.

energy with which to project the human voice through that vast stretch of space between Arlington and Paris. Then, as if the spanning of the Atlantic were not a sufficient accomplishment, the telephone engineers immediately followed up this feat by talking between Arlington and far away Pearl Harbor in Hawaii, a distance of 7,800 miles. That was in 1915, the same year that the trans-continental telephone line was inaugurated—an astounding engineering achievement also due in large measure to the application of the vacuum tube, this time as a perfect “repeater” to build up attenuated voice currents at intervals along their trying journey from coast to coast.

From 1915 on the story of the radio telephone moves along at an accelerated pace through the exciting days of the World War. With our entrance into that fight, we found it necessary to develop the radio telephone as a means of rapid communication between airplanes and the ground. Better radio transmitters had to be developed, for the long stretches of wire of the field telephone and the field telegraph are not practicable in the face of devastating high-explosive barrages of modern warfare. Compact and readily portable loop-type receivers had to be developed to take the place of cumbersome aerials, especially in trench warfare. In truth, it is safe to say that years of normal radio development were crowded into as many months in those days of great anxiety.

Then came 1921. The Westinghouse organization became engaged in a series of radio telephone experiments for the purpose of testing certain microphones and radio telephone transmitters. Soon the radio amateurs took keen interest in those experiments. After a while the Westinghouse organization found that its experiments were coming to be looked upon as a public institution. Aside from radio amateurs,

who were then and are still primarily interested in communicating with one another by means of the dot-dash language of the telegraph code, numerous laymen were buying receiving apparatus so as to listen in on these experimental talks and phonographic concerns which could be snatched out of the air. The Westinghouse organization was keenly alive to this popular interest in radio telephony, and proceeded to inaugurate radio programs on a schedule basis.

So radio broadcasting came about, and the rest of the story is of too recent origin to require lengthy reiteration at this time. If anything, it is the present vacuum tube which has made radio broadcasting possible. The pioneer workers, making use of the troublesome and uncertain carbon arc for generating the radio waves, were hopelessly handicapped. Not only was the carbon arc most inefficient in the generation of radio energy, but such energy as it did produce had to be handled more or less directly with a microphone which could not stand up under such an electrical strain. Back in our 1909 experiments we had to change microphones about every five minutes—and each microphone cartridge cost us about \$3.00!

Now the vacuum tube is the marvel of modern electricity. It can be used to convert direct current into alternating current of very high frequencies, suitable for radio transmission. Feed it alternating current of any frequency, all the way from the high frequency radio waves to the low frequency lighting current, and it will convert such current into direct current. It may be used to detect delicate radio waves; in fact, it is a super-sensitive detector in radio work. The vacuum tube acts as a relay or regulating device, in that it will impress on a powerful current every characteristic of a weak current. It is this facility which permits of using the vacuum tube as an amplifier in

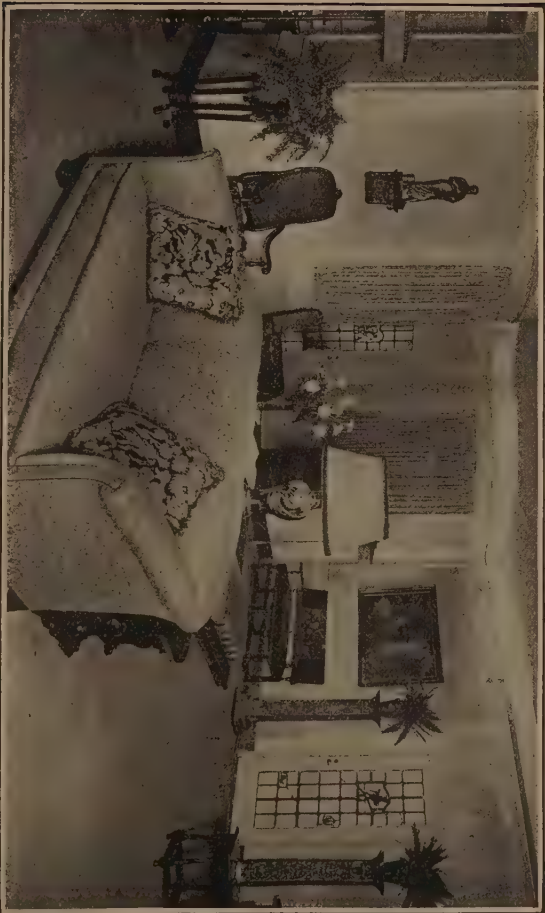
radio receiving, or as a modulator in radio transmission, when the delicate voice currents are impressed on the powerful transmitting waves, or as a repeater in the long-distance telephone line, when it becomes necessary to boost up the attenuated telephone currents at the end of every so many hundred miles of line.

THE GENTLE ART OF BROADCASTING

How quickly we have become accustomed to broadcasting! Only a few years back we were contented to spend our evenings reading the newspaper, a magazine or a bulky book. If we desired a little entertainment, we went to the nearby motion picture house or to the theatre. Or we even called on our friends in order to pass the evening.

Today it is quite different. On our way home we look through our newspaper for the radio programs. We learn what is going to be put on the air tonight for our entertainment. Not only do the radio programs tell us the names of the artists and the speakers as well as their offerings, but also the exact time when we can look for those very features. Instead of having to go out for our entertainment, we have merely to turn on the vacuum tubes, adjust the dials of our radio receiver to the proper settings, and the entertainment comes to us from out of the sky. It is now too commonplace, this wonderful thing called broadcasting, to be fully appreciated.

And if broadcasting has meant so much to the city dweller surrounded as he is with theatres and clubs and libraries and lecture halls, what a boon it has proved to the rural dweller, heretofore quite out of touch with metropolitan life. Now the rural dweller holds nightly communion with the life of the city. He listens to the latest songs; he hears speeches by the



Corner of a typical radio broadcasting studio reception room, where the temperamental artist is made to feel quite at home, awaiting his or her turn to "go on the air." The two doors lead to separate broadcasting studios, while the draperies in the center background conceal a loud-speaker which entertains the entertainers while they wait their turn.

great men of the country; he attends banquets and sits close up to the speakers; he goes to the best shows; he receives the stock reports, weather reports, news of the day, and other items—right in his very home, through the medium of his radio set. The evenings are not as long and as lonesome nowadays. The winter is not looked forward to with such dread as formerly; for, while the winter may mean cold weather and snow, indoor life and firing the furnace, it also means excellent radio reception, as clear as crystal, and the bringing in of radio concerts and talks from great distances.

And then there are the so-called "shut-in"—those poor unfortunates whose physical condition compels them, week after week and month after month, to remain in bed. What a boon this radio broadcasting thing has been to such folk! Indeed, a simple radio receiving set alongside the bed of the "shut-in" has made all the difference between making that "shut-in's" lot bearable and quite intolerable as heretofore. Already, many hospitals are equipped with radio receiving sets, and the time must soon come when virtually all "shut-ins" will have radio entertainment to wile away the long days of enforced inactivity. There have been in the recent past certain campaigns aimed at raising money for the purpose of providing inexpensive crystal receiving sets for "shut-ins". Nothing could be more charitable, to be sure.

PUTTING IT ON THE AIR AND TAKING IT OUT OF THE AIR

There are two phases to radio broadcasting: first, the talk or the music must be put on the air by means of a radio telephone transmitter; secondly, the talk or the music must be taken out of the air by means of a receiving set. Of course, the same thing applies to the wireless telegraph, but in this present discussion

we are not interested in the dot-dash messages of the wireless or radio telegraph which flash through space at the same time as our radio programs, but which, thanks to the matter of wave length "channels", usually keep well out of our way so that they do not interfere with our radio entertainment.

The radio waves which carry the talk or the music are strongest when nearest to their source, and gradually grow weaker as they spread out in ever-widening circles to the vast radio audience. The object of the receiving set is to intercept a small portion of the desired radio wave in its immediate vicinity, by means of "tuning" or adjusting the frequency of the set to the desired wave, and then convert the energy of the radio wave into a replica of the original sounds. The nearer we are to the broadcasting station, the more powerful the waves and therefore the more radio energy can be intercepted. Furthermore, the more powerful the radio energy that is being handled by the receiving set, the simpler the apparatus required for a given strength of sound reproduction. Thus for nearby reception, one need have nothing more elaborate than the simplest kind of so-called crystal set, which will receive with any kind of antenna or elevated wire system for intercepting the radio waves. Even an ordinary umbrella will serve to intercept the radio waves, because of its metallic ribs.

However, remove the listener to a point five hundred miles farther from the same broadcasting station, and it now becomes a question of using the most elaborate type of receiving set if that same station is to be intercepted. The simple crystal receiver is no longer of any use in such a case.

The amount of radio energy delivered by the broadcasting station transmitter is another important factor. The greater the amount of energy emitted by the trans-

mitter, the more powerful the effect of that station on the receiving sets tuned to its wave length. At a given distance, the available radio energy from that transmitter will be greater than that from a weaker transmitter. Consequently, the receiving apparatus may be simpler and less expensive for a given strength of reproduced signal.

All of which may be quite elementary but is really necessary in preparing us for an understanding of the present trend of radio broadcasting.

AT THE MICROPHONE END OF BROADCASTING

Radio programs originate in the broadcasting studio. Hence it is in order at this time to have a few words regarding the modern broadcasting studio from which emanates our radio entertainment.

Minute attention to detail is responsible for much of the improvement in acoustic properties which has marked the trend of radio broadcasting. The early studios were not much to gaze upon and even less in which to exploit one's musical attainments. Little or no thought was given to the acoustics of the studio, with the result that all kinds of troublesome echoes marred the musical rendition and therefore the radio transmission. Still, no great harm was done; for even if the acoustics of the studio had been all that could be desired, the crudity of the radio equipment then in use, both for transmission and for reception, would have marred the radio music.

Today, however, things are quite different. The broadcasting studios are designed and constructed with that consummate care that comes as the result of real experience. Furthermore, the radio equipment, both at the transmitting and receiving ends, has been developed to a very high efficiency from the acoustic stand-



Playing the piano for the unseen radio audience. The microphone, shown at the right, is the link that connects the radio performer with the vast radio audience. The proper placing of the microphone is indispensable for the proper broadcasting of a given musical number.

point. The early receiving sets were primarily radio telegraph sets, especially as regards the transformers used for amplifying the weak sound currents. As a consequence, many musical notes were sadly lost in the radio shuffle, even if they did survive the crude equipment at the transmitting end.

The usual broadcasting station has a studio in which the radio entertainers perform; a control room, in which the delicate voice currents are controlled and built up; and the radio transmitter proper. It is interesting to note how the human voice is built up for radio transmission. Careful measurements have indicated that the power of the human voice, in loud speech or song, is equivalent to about one-hundred-millionth of a watt, according to Dr. Alfred Goldsmith, the well-known radio telephone authority. This incredibly tiny amount of power is yet sufficient to be heard by the ear for a few hundred feet. The ear is therefore a most sensitive instrument and, in fact, is about as sensitive as the eye itself, so far as the amount of power required to give a definite sensation is concerned.

PUTTING HORSE-POWER BEHIND THE RADIO VOICE

But we have desired in radio broadcasting to extend the scope of the voice of man from a few hundred feet to hundreds of miles or even thousands of miles. Therefore, we must produce an approximate "one horsepower voice," or, as it is more usually called, a 500-watt transmitting station. To put the matter another way, we have to increase the power of the human voice over 50,000,000,000 times. And again in other words, if every one on earth were to get together and shout at once the voice power produced would still fall far short of the strength of the voice of the broadcasting station. In fact, the world's call would only be

about one-thirtieth as strong as that of the broadcasting station. It is little wonder, therefore, that broadcasting stations can be heard so far under favorable conditions, by which we mean those when the night is "electrically silent" or free from those electrical disturbances or static, which cause noises or crackling sounds in the head 'phones or loud-speaker and thus prevent our hearing clearly the distant call of the transmitting station.

How the power of the voice is built up for radio transmission is an interesting story which might well be told at length but for our space limitations. Suffice it to state that this feat is accomplished in stages, although it is practically instantaneous, involving five to ten vacuum tubes and in some cases as many as fifteen. Each vacuum tube increases the power of the voice current which it receives, until the final tubes give the full power for broadcasting. The systematic amplification of the voice starts with some low-power vacuum tube, such as those used in our receiving sets, of which as many as twelve or as few as three may be used, depending on conditions. From these are fed the more powerful tubes, which give an output of five watts each in some radio installations. The power of the voice, now enormously increased, passes into 50-watt vacuum tubes, and finally into the so-called power tubes, each of which generally has an output of 250 watts. It will be noted that a graded series of tubes is used, since it would be uneconomical to use power tubes at the beginning of the amplification, where only small amounts of power have to be handled. From the power tubes the radio voice, now in the form of radio waves, is propagated through space, to be intercepted by the receiving sets.

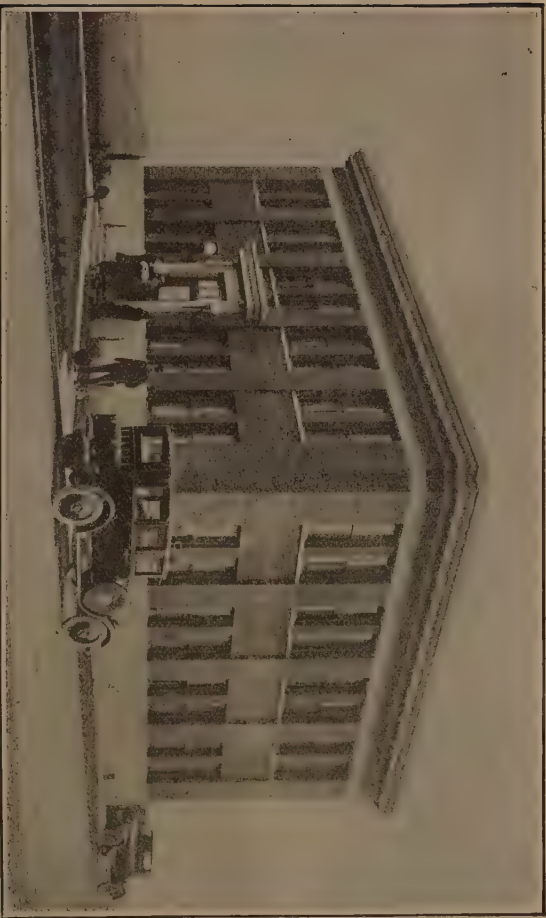
Strange as it may seem, the radio receiving sets intercept only an infinitesimal portion of the broad-

casted power, and again the process of building up the weak radio voice must be undertaken. In the more elaborate types of receiving sets for covering exceptional ranges, the radio voice energy is passed through several tubes of so-called radio-frequency amplification and through the detector which converts this radio energy into so-called audio-frequency energy; then, the audio-frequency energy, representing the original radio voice, is passed through one or two tubes of the so-called audio-frequency amplifier until it reaches the head 'phones or loud-speaker, where the audio-frequency current actuates a diaphragm which is caused to vibrate and set up sound waves that make up a more or less faithful replica of the original radio voice in the broadcasting studio.

THE BROADCASTING STUDIO OF TODAY

To give an inviting and homelike appearance to the broadcasting studio, much care is taken with the general appointments and furnishings. Indeed, the usual broadcasting studio might just as well be the living room in the better kind of American home. Contrary to what the uninitiated might expect, there is usually no suggestion of radio in the studio. Even the microphone, or sound pick-up device, is made as inconspicuous as possible, and that is the only suggestion of radio—the link between the studio and the outside world.

Just as the phonograph recording engineers have had to give much thought and no end of experimentation to acoustics, so the radio engineers have had to study that most difficult of things—sound. In a typical broadcasting studio we find the parquet floors laid in pitch and insulated from the walls of the studio. False walls may be used between the studio and the public hall of the building, so as to introduce a dead-air space,



Present-day broadcasting studio building, containing all the facilities for the handling of radio programs. The aerial and actant radio transmitting equipment are located some distance away. The heavy investments made in radio broadcasting stations bespeak of the permanency of this new art.—(See page 27.)

making it practically impervious to sounds in the hall. The draperies on the walls are so **hung** that they can be adjusted to give the correct degree of deadening for the particular music being transmitted. For instance, heavy brass bands require more deadening than a quartette or a pianist. A speaking voice requires the least deadening for good transmission. In every case the studio director can make his corrections and adjustments without loss of time in the well-managed studio.

Most broadcasting stations have but one studio, which is found to be ample for their requirements. Some of the larger broadcasting stations, however, have two studios, so that the performers may be arranged in one while the other is "on the air." In the case of the WEAf station in New York City, which represents the highest development of the broadcasting art, there are two studios, a small one for singers, speakers and small groups of instruments, and a second large studio for band, large choruses and orchestras. Between the two studios is the announcer's booth from which the programs are directed.

The use of two studios improves the running off of the programs, because it obviates much of the delay to which the radio audience is subjected when single studios are used. While an orchestra is assembling in the larger studio, the radio audience is being entertained by soloists or speakers in the small studio. And when the large studio is in use, an artist or speaker is preparing to broadcast in the smaller studio. In this manner programs can be run off with a minimum of delay and devoid of those long intermissions which are so annoying to the radio audience.

The announcer's booth is characteristic of the WEAf station. It has large windows opening into the studios on either side, thus enabling the announcer to see exactly what is going on in each studio. By means of simple switches he can "put on the air" the various

microphones as required. These include the regular and the emergency microphones in the small studio, in the large studio, in the announcing booth and those installed at remote control points, such as theatres, auditoriums and the like.

The announcer's booth is especially sound-insulated so that practically none of the music from either studio is radiated into the booth. The booth is of terra cotta structure lined with alternate layers of felt and sheet iron. The booth windows are of double plate glass with a dead-air space between, and are hung in piano felt.

Within this booth is located a small monitoring loud-speaker, actuated by the current output of the studios. The announcer thus hears the studio music exactly as it is sent into space for the radio audience, and thus controls the placing of instruments and the action of performers in the studio as determined by the radio output; that is, from the standpoint of the radio audience. This novel feature eliminates the mistakes in placing of instruments which occur when the announcer or studio director is in the studio where the artists perform, so it would seem.

A special loud-speaking equipment enables the announcer to give instructions to artists in each studio and to check up the correct pronunciation of titles and names of selections while broadcasting is going on from the other studio. Through this loud-speaking equipment, also, all announcements are made available to the artists in the studio. In this way each artist knows how he is introduced to the radio audience and is ready to follow the announcer promptly.

In the WEA F studio which we have been describing, there is a large and comfortable reception room with doors leading directly into each studio. This room serves as a waiting room for a large number of artists. A special loud-speaking equipment furnishes

them with entertainment while they are waiting in the reception room. In order to prevent unauthorized entry into the studios, particularly while broadcasting is going on, an unusual type door knob is provided which cannot be opened by anyone unless he knows the special combination. In this way, interruption of broadcasting is made very unlikely.

BEHIND THE SCENES AT THE BROADCASTING STUDIO

The so-called plant department is adjacent to the WEAJF studio. Here all studio and remote control circuits terminate in a power input panel and are connected with the telephone line which runs to the radio transmitter proper, located some distance away on top of a tall building in the heart of New York. A system of adjustable distortion networks is located in the plant department so that the attenuation of lines controlling broadcasting from remote control points can be suitably equalized for radio broadcasting purposes. All remote control is thus handled at one point by a specially trained crew.

In the radio transmission room, on top of a building about a mile distant, there is the radio transmitter with a radio operator in charge. All the while the radio transmitter is "on the air," the operator is required by law to listen in on the 600-meter wave length, which is the wave length employed by ship stations for SOS or distress calls. The moment an SOS call is picked up, or when a Naval station orders the broadcasters off the air, the operator at the broadcasting station immediately shuts off the transmitter and notifies the studio manager by telephone. This accounts for the sudden cessation of broadcasting on rare occasions, no announcement of the SOS being made by the broadcasters until the resumption of their programs.



All the while a radio broadcasting station is on the air, an operator must listen-in on the 600-meter wave length which is reserved for the SOS calls of ships in distress. It is the operator who shuts off our programs at the first intimation of an SOS call.

One of the interesting features of broadcasting which are not generally appreciated by the radio audience, is "monitoring." In every properly managed broadcasting station there will be found a keen young man—and sometimes a young lady—intently watching the fluctuating needle of a meter and constantly manipulating a control knob while music or other features are being broadcasted. This "monitoring" has to do with overcoming the wide variation in volume which must be handled in the case of certain musical instruments. For speech, the variation in average power is of the order of 1,000 to 1. In music, and especially that delivered by a symphony orchestra, the energy variation between the softest and the loudest passages may be as great as 100,000 to 1. In the present state of the electrical art it is not practicable to handle such an enormous range of volume in broadcasting. This limitation arises not so much from the capacity of the broadcasting apparatus as from the existence of extraneous noise. The softest musical passages when broadcast must be made sufficiently loud to over-ride static and other electrical interference in space, as well as receiving set noises and any incidental noises. Were the softest passages to be made loud enough to overcome such extraneous interference, it would be extremely expensive to provide the equipment for making the loudest passages 100,000 times as loud. Consequently, good broadcasting requires a skilled listener and a monitoring device. The function of the monitoring operator is to adjust the amplifier in the broadcasting system so that its output will take into account the changes in loudness of the program. These changes in volume must not be unduly reduced, but they must be made such as will carry best to the radio audience without overloading any element in the broadcasting system.

THE OLD QUESTION OF QUANTITY VERSUS QUALITY

The latest statistics disclose that there are in the United States and Canada something like 600 radio broadcasting stations. Of this number, approximately 130 are using 500 watts or more. These stations are scattered so as to blanket the entire North American continent.

At first thought this would appear to be a splendid thing—six hundred broadcasting stations putting as many programs on the air day after day. Surely, one need never worry about picking up an enjoyable program, in view of the variety offered by the combined efforts of the broadcasters. But unfortunately, this is one case where quantity is of secondary consideration, if, in truth, it is not of the very first consideration after all. With so many high-power stations there is, if receiving conditions are good, as in the cold, crisp, winter evening, a considerable overlapping of wave lengths and, as a result, more or less interference. Hence the listener-in needs a high-grade set in order to pick out any particular station and bring it in so that the quality is good. This is especially true if he is located in the vicinity of one of the undesirable stations.

Then, to make matters worse, the public is bent upon long-distance reception. Why it is essential that we listen to the impossible program of the Podunk station, when the nearby station is broadcasting Paul Whiteman's famous dance numbers or the Philharmonic orchestra, would be a deep mystery except for the fact that Podunk is 2,281 miles distant. Distance lends enchantment. And there you are.

In an effort to obtain distance, in too many cases the listener tries to "get" stations that are beyond the proper capacity of his receiving apparatus, which results in forced regeneration in what is known as the regenerative receiver—a type that is still widely used.

Forced regeneration causes the receiver to act as a miniature transmitter which emits a radio wave of about the same wave length as the station that is being listened to with more or less success. Meanwhile, other listeners-in within a quarter of a mile or more are picking up the emitted wave which now gives rise to a whistle in their head 'phones or loud-speaker. This case, multiplied by dozens of others in the small community, or by thousands in the large city, results in a bedlam of whistles, groans, shrieks and what not which break up the radio programs for many of the radio audience. Unfortunately, in the recent past our short-sighted radio manufacturers have flooded the country with regenerative sets of the most offensive types.

In many localities the conditions in this respect are deplorable. Broadcasters who take particular pride in their efforts are temporarily discouraged over this situation. The worst offenders in the production of these radio "birdies" are the builders of crude home-made sets. Sad to relate, the regenerative receiver is the simplest, cheapest, and most effective type of receiving apparatus for the efforts of the amateur builder. To make matters still worse, the irresponsible dealers in radio equipment are forever dressing up the old regenerative receiver in some slightly different style and selling the parts to the gullible public under a new and high-sounding label. Were the regenerative receivers to be placed only in the hands of skilled and conscientious radio amateurs, there would be little if any of the unbecoming noises now heard; for, truth to tell, the regenerative receiver when properly operated does not emit a disturbing wave. In Great Britain, where our trials and tribulations as pioneers in this radio broadcasting art have been carefully studied, a regenerative receiver of any kind is positively tabooed.

A BETTER RECEIVER OR MORE POWERFUL TRANSMITTER— WHICH?

What is the remedy for this condition? That is a question which broadcasters and the radio industry and listeners-in have been asking themselves. In truth, this is the gravest problem which confronts the broadcasters, apart from the economical side which is quite another story.

There seem to be two remedies available in solving the present state of the air: first, the use of receivers which will not and cannot emit a wave of any kind; secondly, to bring the transmitter nearer to the receiving set either by piling on more power in our present broadcasting stations, or by installing more broadcasting stations at various points nearer to the listeners-in, and operating these stations as "repeaters" of a single program sent out from some central or primary station.

Maintaining its pioneering spirit in the broadcasting field, the Westinghouse organization has taken the initial step toward solving the present situation through the transmitting end. Instead of placing the burden on the radio audience, this organization has been working out a means of bringing the programs nearer to the receiving sets.

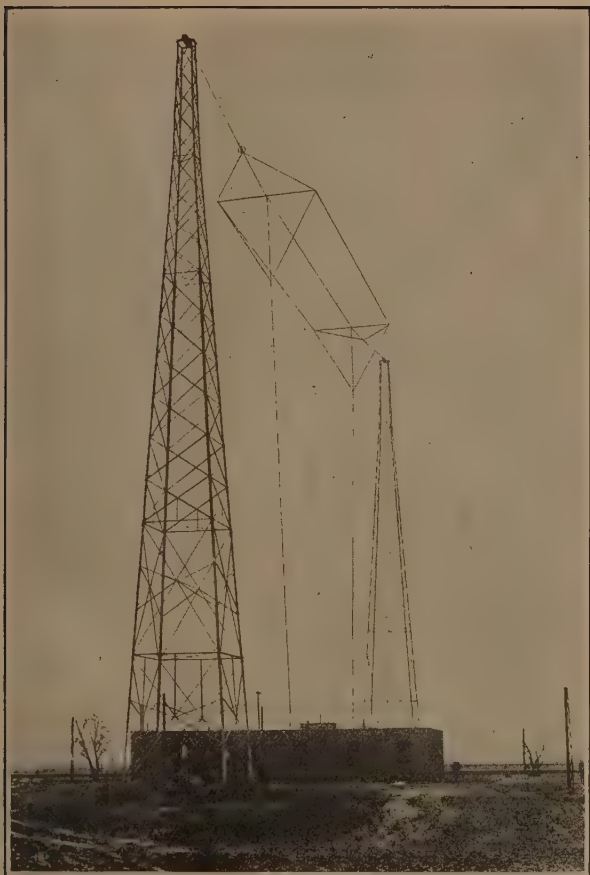
Here is how the thing can be done: Suppose we have a studio in New York, broadcasting the finest type of programs. In order to bring those programs within reach of the listeners-in throughout the Middle West, let us say, we must operate a powerful station somewhere in the Middle West. The same programs are to be re-broadcasted from the Middle West station, which is therefore a repeater station. Two methods are available for performing this service, one by telephone wire transmission between the New York studio and the Middle West repeater transmitter, and the other by the special wireless transmission of the pro-

grams—quite distinct from the regular broadcasting wave—the special waves being intercepted at the repeater station by means of a suitable receiver, and then led to the transmitter for re-transmission.

Now imagine, if you will, a number of these repeater stations located throughout the United States. This arrangement would give the radio audiences in every part of the country the finest programs available, indirectly from the Gay White Way or from the Nation's Capitol, in ample volume so as to be intercepted with the simplest receiver. Obviously, the repeater station could also function as a primary broadcaster, whenever something of local interest was to be put on the air.

The telephone wire transmission seems the simplest means of accomplishing the desired end. Simultaneous broadcasting by a number of stations, widely separated, has been carried on at intervals by wire transmission, for some time back. Unfortunately, however, the limitations of this method are considerable and the difficulties of repeating programs increase with the distance and the number of stations; so that while it is technically possible to do this work in this manner, from the cost standpoint it appears entirely impracticable at this time. In addition, a most serious limitation is the lack of flexibility at the repeating station, to permit it to shift from one program center to another, as it would be impossible to change the telephone wire connections without elaborate prearrangement.

Radio repeating, on the other hand, has no such limitations and possesses flexibility to the utmost degree. While only one such station—the Westinghouse station at Hastings, Nebr., KFKX—is at present in commercial operation, the success already attained with this station is sufficient to demonstrate the possibilities of this method of repeating, and to indicate



The aerial of a radio broadcasting station, as well as the building containing the transmitting equipment. The studio is located in another building, some distance away.—(See page 17.)

that it marks the first step toward a comprehensive system of radio repeating which will, in time, cover not only the United States, but the entire world, according to H. P. Davis, Vice-President of the Westinghouse company. Under this system, we are assured, it will be possible to listen in on the interesting events of the old and the new worlds.

The system is so flexible that it is susceptible of indefinite expansion without excessive cost. When completely worked out, the owner of every crystal or low-power set, no matter where located, can listen to selected programs in which the best from every quarter of the globe can be included. The primary broadcasting stations need be but few in number, but will be located where the best program material is available.

How does this radio repeating work? Simple enough—at least now that it has been worked out by radio engineers after several years of painstaking efforts. The KDKA station of the Westinghouse organization, the pioneer broadcaster, please remember, broadcasts two waves at one time. The regular broadcast audience is being entertained by means of the 326-meter broadcast, while a 94-meter short-wave broadcast is going out to the repeating stations. Tests have proved that the short-wave or high-frequency broadcasts go farther with the same-power input than the ordinary broadcast waves. It has also been proved that daylight, which has a marked effect on the usual wave lengths, has little effect, if any, on this carrying power.

Great things are bound to come out of this short-wave transmission and re-broadcasting. On many occasions the concerts broadcast by KDKA have been picked up in London on a short-wave receiver, properly amplified, and re-broadcast on the higher wave lengths used by the British broadcasters. The Pittsburgh concert, via London, has been picked up in Calcutta, India,

and held for thirty-two minutes. This system of short-wave transmission and repeating is enabling the British audiences to listen to American radio programs, and even the French, Belgian, Dutch and German listeners-in may have an opportunity of listening to the fascinating strains of American jazz via the British repeating stations.

DOING AWAY WITH THE "PICK-UP" WIRES

The possibilities of short-wave transmission penetrate even deeper than this into the future of radio broadcasting. Broadcasters from time to time find it necessary to transmit directly from some point outside the studio. It may be a banquet, a baseball or football game, the ringside, the theatre or opera, the convention hall; but whatever it is, the usual studio microphone is replaced by a microphone in the field, so to speak. The "pick-up" equipment, to use radio parlance, has heretofore been connected with the broadcasting station by means of telephone or telegraph wires. Such means have been ample for the purpose, although, truth to tell, there have been many times when the broadcasters have found it difficult and, sometimes, impossible to obtain the proper wire connections, with the result that the radio audience have missed important events. And now we have short-wave transmission coming in to fill the rôle of the ideal link between "pick-up" microphone and broadcasting station. A short-wave transmitter, located at the very scene of the radio feature, can now be employed to pick up the sounds and transmit them through space at an undetectable frequency, so far as usual receivers are concerned, to the nearest broadcasting station where the feature is received, amplified, and re-broadcasted on standard wave length for the radio audience; and, furthermore, if this station is a primary broadcasting station, the feature is put on the

air at an undetectable or repeating frequency which will have high power to obtain distant transmission. This latter wave will be picked up by a chain of repeating stations.

There are a good many possible paths in the ether for these repeating waves, so we are assured by radio engineers; and with a sufficient number of properly located high-power repeating stations an indefinite number of programs will be made available for the secondary broadcasting stations of low power, which will repeat and broadcast at a frequency or wave length detectable with the usual receiving sets.

THE QUESTION OF DOLLARS AND CENTS

Aside from the solution of several of our present technical troubles, the short-wave repeating scheme tends to solve the economic phase of broadcasting. Long has it been predicted that at some future time many of the independent broadcasters are bound to give up broadcasting, in that there are no tangible returns for their efforts and the expenses of broadcasting are steadily mounting higher and higher. Then, too, it seems but a matter of time when our radio entertainers, who now give their services so willingly for whatever publicity and general satisfaction there may be in broadcasting their efforts, will demand remuneration for their services.

Please note how this economic phase is met by the short-wave transmission from the primary broadcasting station and the repeating stations scattered throughout the country. The primary station, located in the metropolis, is in a position to get the finest talent of the land. If the artists must be paid, then the expenses can be distributed among all the repeating stations over a wide expanse of the country. Even at the present time the American Telephone & Tele-

graph Company has such a plan in actual operation. Instead of short-wave transmission, this company, with its splendid network of telephone wires, makes use of telephone links to tie up the master studio with the re-broadcasting stations. In Washington the telephone company maintains a special re-broadcasting station, WCAP, which handles the same programs as the WEAJ station in New York City. Then, too, the New York programs are sent by wire to certain stations in New England, which re-broadcast to their local audiences. Whatever expense may be connected with the securing of the programs can certainly be apportioned among the various broadcasting stations in such an arrangement, thereby tending to solve the great economic question of broadcasting.

AND AT THE RECEIVING END

While the broadcasters are working on the problem of moving the programs up nearer to the listeners-in, radio engineers are at work on better and still better receiving sets. For, let us admit, many of us like radio "fishing" best of all—this business of seeing how many stations we can pick up in one evening, and how far. The author cannot help but indulge in a little reminiscencing at this point. His thoughts go back to those winter days in 1909, when he was working a crude two-slide tuning coil and a crystal detector while trying to pick up the dot-and-dash message from Fort Wood which was to tell us how we were coming through with our radio telephone transmission. The author fussed and fussed, but without success. Everything but the desired station could be heard in the head-phones; indeed, even a passing battleship had just called us up, with the short but sweet message "For C—'s sake change the tune!" The operator aboard the battleship was referring to our Anvil Chorus, which

had just been played for the fifty-first time. At any rate, we finally resorted to the Postal Telegraph wires in the nearby ship-reporting tower then in use at Sandy Hook, as a quick and reliable means of hearing from our collaborators but eighteen miles away.

Fifteen years later the author sits before a neat cabinet with two simple dials on which are marked the call letters of various stations, both local and long-distance. The author glances at his watch; it is two o'clock. Then he looks through the radio program columns of the newspaper—it makes no difference what newspaper, for all newspapers *must* carry the broadcast programs of the day.

There is a program in Philadelphia at two o'clock. There is another program in Providence. Still another is on the air from Cleveland. One New York station is working at this hour. Very well. The two handles are turned until the dial pointers indicate the New York station. Instantly a violin solo comes out of the flared horn of the loud-speaker, standing alongside the long cabinet. The two handles are adjusted for the Philadelphia station, and out comes the voice of a well-intentioned lady speaking on some subject or other which has little appeal to masculine tastes. Once more the handles are adjusted until the indicators point to the Providence station. Instantly, the strains of an orchestra come drifting out of the horn with plenty of volume to fill the room, yet soft and sweet and most life-like. We linger a while, because this feature suits our particular tastes. What a boon, this business of being able to choke off undesirable programs and to select desirable ones! Finally, we set the dials again; this time for Cleveland, a fair pianist.

The set in question is entirely self-contained. There is no antenna connection. No ground wire is necessary. Inside the set is a small oblong frame with a dozen turns or so of wire, known as the loop, which serves

to intercept the radio waves. That little loop takes the place of the elevated wire measuring 100 feet or more in length, heretofore required for radio reception.



The broadcasting of organ music, a most difficult task, has finally been mastered. Note the position of the microphone in the upper right-hand corner.

Furthermore, this set contains a few dry cells to operate the six vacuum tubes. The only external connection is that running to the loud-speaker. And even when the set is being carried about, in the automobile, street car, canoe—anywhere, the radio waves from stations several hundred miles away can be intercepted and reproduced good and loud.

THE ROLLS-ROYCE OF RADIO

Of course this particular type of set is admittedly, the 1924 model Rolls-Royce of receiving sets. It is known as the Armstrong super-heterodyne, having been developed back in the World War days by Major Armstrong—that same young man who was working on the crude vacuum tube circuits during his college days in 1913. The super-heterodyne takes the weak energy intercepted by the small loop, plays it off against a locally generated wave, and the resultant wave is passed through radio frequency amplifiers at high wave lengths, because the so-called untuned radio-frequency amplification is most efficient at high wave lengths, and on to the detector. This arrangement makes for the utmost efficiency with simplicity.

But why say more at this time? Let us take up the study of radio, step by step, in the chapters that follow, in a practical and understandable way, devoid of dry technicalities.

CHAPTER II.

THE A B C OF RADIO COMMUNICATION

IF the automobile has made us a race of mechanics, the radio is fast making us a race of electricians. As a matter of everyday conversation we hear men and women and boys discussing radio circuits in a manner that would have done justice to a radio expert of the recent past. We have the average man buying divers parts and making his own set with the skill and the neatness that have heretofore characterized the work of electrical specialists. Newspapers are publishing special sections and supplements devoted to the intricacies of radio which, but a few years ago, would have been the proverbial fish out of water in the columns of the daily press.

While it is true that the general public is interested first and last in radio programs themselves rather than the radio apparatus employed, the public cannot help but take some interest in the subject of radio communication. Radio is forever undergoing a process of evolution; no matter what receiving set may be used, there is always an opportunity present of making it more effective. Hence the radio listener-in, while mainly

interested in listening to the radio programs, *must* and *is* taking an interest in the radio apparatus which he is using as the means to the end.

PUTTING RADIO PROGRAMS INTO THE AIR AND TAKING THEM OUT AGAIN

Although radio is a difficult and intricate branch of electrical engineering, its practical rudiments may be readily absorbed by the average layman. Its principles can all be explained in a simple and elementary way.

To begin with, radio communication, whether it be the radio telephone or the radio telegraph, is based on a *cause* and an *effect*, separated by a greater or less distance. The *cause* is the transmitter, which sets up certain disturbances or waves in space which travel in all directions until they reach a distant point and create the desired *effect*, which is the result obtained with the receiving set.

In the instance of the radio telephone, the cause is the radio broadcasting station. There are over five hundred radio broadcasting stations in operation today, scattered throughout this country; indeed, virtually every section of the country is now served with music, news of the day, weather forecasts, crop and market reports, and so on. The radio telephone transmitter sets up disturbances or waves in space which travel in all directions. These disturbances or waves may be intercepted at any point within the range of the transmitter, and when so intercepted can be brought to suitable receiving instruments and reconverted into the original sounds of the music or talk, as the case may be, so as to give a faithful rendition to the radio audience. That is the *effect*.

Now, just how the disturbances or waves are set up and how they travel through space is a problematical matter. There are numerous theories offered to explain

how the waves emitted by the broadcasting station cause an effect at a distant point. Until the great German physicist, Einstein, came along and upset many of our pet theories with which we had been explaining so many things during the recent past, it was usually held that a radio transmitter set up vibrations or wave motions in the ether. The ether is the name given to a hypothetical substance held to exist everywhere, even in a vacuum. However, with the ether explanation rendered more or less obsolete by Einstein, our pet radio explanation has been rather rudely shattered.

Still, for all practical purposes we can state that certain kinds of waves of an electromagnetic character are produced by a radio transmitter, and that these waves travel through space at the astounding speed of 186,000 miles per second. These waves have much the same characteristics as the waves which we call light, except as regards wave length and frequency of vibration. Whereas the waves of visible light have a length to be measured in millionths of a millimeter, and a frequency of vibration of billions per second, the waves used in radio work are seldom less than 100 meters in length, and may be as long as 20,000 meters or more in the case of long-distance, high-power transmitters such as those which span the Atlantic and the Pacific oceans. At the same time, the frequency of radio waves is to be measured in millions down to thousands per second. These radio waves pass through space and pretty much through everything that stands in their way. They pass through stone walls, frame buildings, mountains, forests, and so on. Certain other things, particularly masses of metal such as a bridge, a skyscraper or a gas tank, absorb a considerable volume of the radio waves. However, the radio waves are usually sufficiently powerful to operate receiving sets within range, despite the absorption mentioned.

The radio waves are everywhere, yet cannot be seen

or felt. Without a receiving set it is impossible to tell if the air is permeated with radio traffic or whether it is absolutely barren. So far as is known, even the strongest radio waves have no direct effect on any of the five senses, which are the sole avenues whereby we appreciate anything that is external to ourselves. Directly, we cannot feel, hear, smell, taste or see the radio waves. While it is true that the eye is a detector of electromagnetic waves such as light consists of, still, the unaided eye can only detect the very short waves of visible light which, as already stated, are minutely short and are all contained within the narrow confines of a single octave; and while by means of certain luminous screens known as fluorescent screens the range and visibility can to some extent be increased, no such method will render visible even the shortest of waves used in radio.

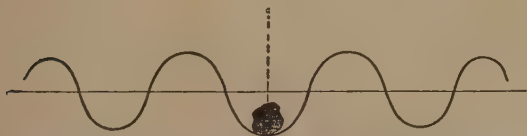
RADIO AND THE POND OF STILL WATER

Other methods have had to be developed to detect radio waves. These methods intercept the radio waves and convert them into some form of energy that comes within the scope of our senses. The receiving set presents the usual means of converting radio waves into sound waves which affect the human ear.

Now let us consider a pond of still water as space, in order to follow the theoretical formation and propagation of radio waves. When a pebble is thrown into the smooth water it starts a series of concentric ripples or waves, which spread out indefinitely with a speed of a few hundredths of a yard per second. Similarly, the electromagnetic disturbances set up by a radio transmitter spread out in all directions in ever increasing circles, at the astounding speed of 186,000 miles per second—virtually instantaneous, in the practical sense. As the waves spread out over the pool,

little bits of straw or grass maybe seen to move as the waves reach them and pass on. These bits of straw or grass may be compared with the radio receiving stations which are likewise affected as the radio waves reach them and pass on.

It will be noted that the waves in the pond grow weaker as they extend farther and farther away from the point where the pebble was thrown into the water. The same thing occurs in radio; as the waves spread away from the transmitter, they become weaker. Here, then, is a radio fundamental. The waves become weaker with distance.



How waves are produced when a stone or pebble is dropped into water. The waves are highest at their source, but rapidly dwindle down in size the farther away they are from the spot where the pebble struck the water.

Now let us study the action of the waves in the pond on the bits of straw and grass. It will be noted that when the waves are powerful, near their source, they affect large and small bits of straw and grass alike. Even a broken twig bobs up and down as the waves go by it. But when the waves grow weaker as the result of their distance from the source, only the smallest bits of straw and grass are affected, while the larger pieces, and especially something as large as a twig, do not respond as the waves go by. The bits of straw and grass, as well as tiny twigs and sticks, may be compared with radio receivers. Thus the more sensitive receivers are responsive to the

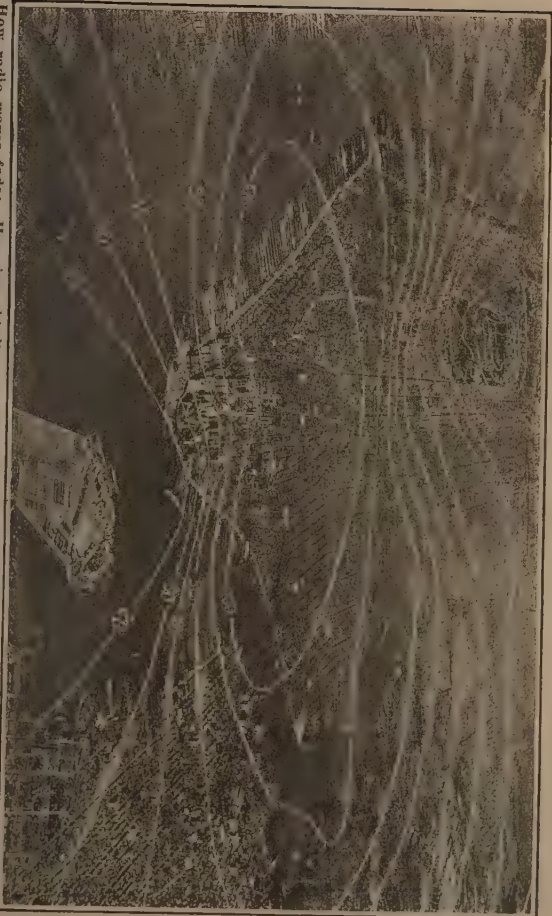
weaker radio waves; which is but another way of saying that the more sensitive receivers will respond to a given transmitter at a greater distance than a less sensitive receiver. This same analogy also points out why a powerful radio transmitter, capable of producing powerful waves, must naturally carry farther than a smaller transmitter.

All of which indicates that the question of distance in radio communication is governed by several factors. Beginners and laymen in radio will insist on being informed how far this receiver or that receiver will receive, and how far this transmitter or that transmitter will send. Such questions are quite on a par with those having to do with the mileage of an automobile. There are so many factors involved in either of these things that it is virtually impossible to supply a satisfactory answer. Yet the laity is greatly perturbed and even indignant when refused a definite answer regarding the performance of a radio transmitter or receiver.

HOW FAR WILL THE RECEIVER REACH?

First of all, a receiving set cannot determine the distance over which it will receive. The transmitter has something to do with the performance. Thus from a powerful transmitter a given receiver may receive at a distance of 1,000 miles. From a low-power transmitter, such as that employed in amateur radio work, the same receiver will span perhaps 50 or 100 miles. It is therefore obvious that the transmitter plays an important rôle in this question of the distances that can be spanned.

If that were all there was to this problem of distances, it would be relatively simple. Unfortunately, however, there are other factors of a most intangible nature. Thus the location of the transmitter has a



How radio waves fade: Here is a bird's-eye view of the lower end of Manhattan Island, with part of Brooklyn at the lower right-hand corner and Long Island City in the upper right-hand corner. The lines and their respective numbers mark off various areas according to the strength of the intercepted signals. In the middle of the center area, with the full strength of 100, is the WEAF broadcasting station.

great deal to do with its transmission in various directions. It is by no means uncommon for a transmitter to send its messages over a distance of thousands of miles in certain directions, only to have its waves dwindle to nothing within 50 or 100 miles in other directions. Many radio broadcasting stations of today have what might be termed "blind spots;" that is to say, they are weak in certain territories which they should serve well on the basis of distance. A case in point is the WEAf station in New York. While operating on the standard 500-watt transmitter, this station had a large number of "blind spots." Even on Manhattan Island, within ten miles of that station, there were certain neighborhoods in which WEAf could not be heard properly. This difficulty has been largely overcome by increasing the power of that station.

What may be said of the transmitter also applies to the receiving station. Thus there are many localities which are called "dead areas" in radio parlance, because they are barely if at all penetrated by the radio waves. Just why there should be "dead areas," is a matter for deep controversy. In some instances it is a question of topography: the "dead area" is surrounded by tall hills or mountains which may contain rich ore deposits. Dense woods are detrimental to radio efficiency. Such obstacles interfere with the passage of the radio waves, and perhaps throw radio shadows, if that term may be permitted. Again, "dead areas" may be due to the nature of the soil. Thus in certain parts of our country, especially northern Michigan, there are times during the year when radio reception is very poor when using the usual antenna and ground arrangement. Here, however, the poor results may be overcome by using a loop receiver, which does not require a ground connection, or substituting a "counterpoise"—a device which will be described further on—for the ground connection.

Still another factor, and perhaps the most important of all in the matter of distance covered by transmitter and receiver, is the medium in which we are operating. Whatever may be the path taken by radio waves, the fact is clearly established that it varies throughout the year and even from day to day. During the cold, crisp winter days, radio range is greatly increased, while during the warm, sultry days of summer, the range is reduced. Again, radio transmission and reception are better at night than during the day. Strong sunlight is detrimental to radio efficiency. Not only is the distance spanned affected by certain atmospheric conditions and sunlight, but the transparency, so to speak, of the conducting medium is greatly impaired. Anyone experienced in radio work comes to look upon the conducting medium as something which changes its transparency—its ease of passing along the radio waves. Sometimes the medium is as clear as crystal; distant radio stations come thundering in; there is a complete absence of extraneous or parasitic sounds. At other times the medium is more or less opaque to the passage of radio waves, and one must be satisfied with the nearby transmitting stations. Also, there are numerous extraneous or parasitic sounds which mar the reception.

STATIC—THE BUGBEAR OF RADIO

These extraneous or parasitic sounds are known as "static." As a general rule, there is no static during the winter months, and little during the late fall and the early spring. Static begins in the late spring, is at its height during the summer, and tapers off during early fall. This does not mean to imply that static never occurs in cold weather, or that there is always static during warm weather. However, it does mean to

imply that static is quite seasonable at certain times of the year, and the absence of static during such times is a rarity, to be sure.

Just what causes static is a much mooted question. Static is the name applied to any electromagnetic waves set up by non-radio apparatus. The greatest producer of static is the atmosphere. A gathering thunderstorm generates static, for even though no lightning may be visible, there are electrical discharges taking place between the clouds themselves, such discharges releasing powerful electromagnetic waves which are heard at the receiving end. An active lightning storm generates the most powerful static disturbances. Even though a thunderstorm may be raging in Chicago, it will affect the more sensitive receivers in New York. However, if the receivers are being used for intercepting nearby stations, the chances are that the static disturbances are weaker at the receiving end than the signals from the nearby transmitters. And that is the reason why static is less bothersome on nearby reception than in long-distance or so-called DX work. Also, that is the reason why the radio listener-in is asked to be satisfied with local programs during warm weather, instead of trying to reach out thousands of miles in search of distant entertainment as during the cold, snappy winter evenings.

With some appreciation of these several factors which enter into the transmission and interception of radio waves, the layman begins to understand why it is impossible to make definite statements regarding distances covered by any given transmitter or receiver. No definite range can be given for any radio instrument; in truth, specific conditions at any given moment decide the range. Otherwise, all statements of range must be considered as approximations of a very crude sort.

THE MATTER OF WAVE LENGTH

Returning once more to the pool of water which has already served so well for our homely comparisons, it will be noted that the waves in spreading out from the source maintain a certain distance between crests. If the distance from the crest of one wave to the crest of another is measured, we obtain the wave length, as represented in *a-b* in the accompanying sketch. In the instances of waves in water, the wave length is determined by the size of the stone, the wave length being greater when a large stone is dropped into the water. In radio, however, the wave length has nothing



The wave length of a wave is the distance from one wave crest to another, indicated by *a-b* in this drawing. The wave length has nothing to do with the power or strength of the wave, which is represented by the height of the crest.

to do with the size of the transmitter, although it is true that short wave lengths are generally employed for the smaller amateur transmitters, and longer wave lengths for the commercial stations, especially the huge transatlantic stations. While the waves are larger and therefore more powerful when a larger transmitter is employed, the wave length is determined by other factors as will be explained further on.

In addition to the distance between crests in our pond waves, which we have called the wave length of the waves, it will be noted that some waves are taller than others. If we measure the distance from the crest of one wave down to the normal level of the water, we have the actual power represented by that wave.

The term for this factor is amplitude. In radio work the power of the wave is represented by the amplitude, which is the electromagnetic potential of the wave without regard to the wave length. In this manner we can have a powerful radio wave from a 500-watt transmitter with a wave length of 360 meters, and a weak radio wave from a 5-watt transmitter with wave length of 1,000 meters, if desired. The wave length does not denote power, it will be noted.

The wave length in radio determines the tuning of the transmitter and receiver alike. By tuning is meant the bringing of a radio circuit into harmony with another, just as we can tune a piano string by tightening or loosening it, until its pitch is the same as that of the desired tone. Radio tuning is nothing more than the adjusting of a receiver or a transmitter to a given wave length, so that it will operate on that wave length. If a transmitter is adjusted or tuned to a 200-meter wave length, the waves emitted will be of 200-meter wave length. As they travel through space in all directions they are intercepted by receiving sets which are tuned to the 200-meter wave length. Other receiving sets tuned to short or longer wave lengths will not respond to those waves. On the other hand, if another transmitter is operating at the same time on a 600-meter wave length, then the first batch of receiving sets adjusted to the 200-meter wave length will keep right on receiving from the first transmitter, while the others adjusted to 600-meter wave length will receive from the second transmitter.

It is this matter of tuning that has made radio communication practicable. Were it not for tuned radio waves, it would be impossible for more than one transmitter to operate in a given area, for the simple reason that confusion would result if several untuned transmitters were operating at the same time. With tuned waves, however, and with adjustable receivers,

it becomes possible to couple a given receiver with the desired transmitter, provided the latter is within range of the former.

Radio wave lengths vary all the way from 90 meters to 12,000 meters and over. The wave lengths below 100 meters are very difficult to handle and cannot be generated or intercepted with the usual radio apparatus available to the amateur and radio enthusiast alike. However, of late these exceptionally low wave lengths are being employed for special repeater work in radio broadcasting, as explained in the first chapter. Radio amateurs make use of wave lengths from 100 meters to 200 meters, being limited to that band by the existing radio laws. Radio broadcasting is permitted on wave lengths running from 250 meters to 600. Higher wave lengths are employed by ship radio stations, Army and Navy radio stations, and finally, when we get up to the higher wave lengths of 10,000 meters and over, we are in the wave length zone of the high-power stations which span the Atlantic and Pacific Oceans.

With the usual radio receiving set the operator can tune in any desired broadcasting station within range with virtually no interference, thanks to this matter of wave length. Tuning enables the operator to go from one program to another.

Another matter which often confuses the beginner in radio is whether there is a limit to the number of receiving stations that can listen to a given transmitter. As a general thing, there is no limit. In the past there has been no practical limit in sight. However, with the vast increase in the number of receiving sets, radio engineers have begun to detect a difference in receiving efficiency due to the number of receiving sets in operation. Major Armstrong, in the course of recent experiments, detected a marked decrease in receiving results when receiving sets in the

vicinity were tuned for a given radio feature. As time goes on and more and more receiving sets come into existence, it is very likely that the drain on the radio waves, caused by the infinitesimal energy intercepted by each receiver, will become quite noticeable, and to overcome this it will be necessary to employ more powerful transmitters or more sensitive receivers that can operate on less intercepted energy.

DAMPED AND UNDAMPED WAVES—WHICH?

The waves which we have been studying in the pool of water are highly damped. That is to say, they die down quickly. The pebble or stone is dropped into the water, the waves start out good and strong, only to die out in short order. In order to keep up the disturbance in the water, it is necessary to drop one pebble after another, so as to create a steady supply of new waves, which occur in groups or "trains." Each group or train soon dies down, and is followed by the next one, and so on.

In radio we have the same condition when the usual spark transmitter is employed. The group or train of waves starts out strong but soon dies down, and a second train of waves must be started, only to die in the same way. Such damped waves may be likened to the action of the usual pendulum. When the pendulum is given a push, it swings from side to side, but each swing is a trifle shorter than the preceding one, until the pendulum comes to a dead stop. Its action is damped, in other words, corresponding to the action of damped radio transmitters.

The damped radio transmitter was the original form used for radio telegraphy. It sets up buzz-like sounds in the radio receiver, each dot and dash being made up of a number of trains of waves. The frequency of

occurrence of these wave trains determines the pitch of the buzz-like sounds in the radio receiver.

Of late years the undamped transmitter, as distinguished from the damped type, has been gaining favor. Unlike the latter, the undamped type produces a steady flow of waves instead of an intermittent flow in trains. Undamped waves are just as though a hinged paddle were used in the pool of water, the paddle being worked back and forth so as to produce a steady series of waves, all of the same size and strength. That is to say, the waves are all of the same wave length and the same amplitude. Or, referring



The difference between damped or discontinuous waves, and undamped or continuous waves as represented by the water analogy. Dropping a pebble into water causes damped waves—waves which drop off in power or height of crest, known as the amplitude, as shown in the upper sketch. Using a paddle, on the other hand, produces continuous waves—waves of uniform power or amplitude, as shown in the lower sketch.

to the pendulum analogy, undamped waves are as though the pendulum were given a fresh push at each swing, so as to restore the initial energy and in this way prevent it from dying down. The pendulum, under such circumstances, would continue to swing with equal length of swings, just so long as the energy were applied.

Undamped wave transmitters are now used in commercial and amateur radio telegraph work. They are also known as continuous-wave transmitters or CW

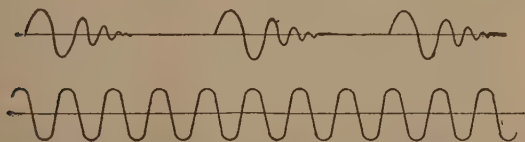
transmitters for short. Radio telephony is always carried on by means of continuous-wave transmission, damped waves being unsuitable for this purpose. In the case of radio telegraphy, the emitted CW waves are chopped up into short and long emissions so as to form the dots and dashes of the telegraph code. In radio telephony, on the other hand, the radio waves are emitted steadily while the station is "on the air," but the radio waves are "modulated" or moulded—the amplitude is constantly changed—by means of the microphone so as to carry the latent sound values. The radio waves are referred to as the carrier waves, in that they "carry" the sound values. The receiver picks up the carrier wave, and the variations in that carrier wave are translated into a replica of the original sounds.

HOW RADIO WAVES ARE CREATED

Electricity may be made to vibrate or oscillate, and it is this vibration or oscillation that creates radio waves. Current from a storage battery or dry battery flows steadily and only in one direction. Current flows out of the positive or + terminal of the battery, through the circuit, and back to the negative or — terminal. That is direct current. There are no oscillations here. Then there is another form of electric current known as alternating current, which is usually generated by machines known as alternators. Alternating current does not flow steadily in one direction, nor does it maintain the same potential or voltage at all times. At a given instant the alternating current is flowing through the circuit in one direction, and the next instant it is flowing in the opposite direction, only to change back to the first direction the next instant, and so on. Each change of direction is known as a cycle. Commercial alternating current, which

is widely used for lighting and power purposes, is known as 60-cycle current, which means that it has gone through 60 reversals of flow, or cycles, in one second, each cycle consisting of a steady rise in positive voltage from 0 to the maximum voltage, and a steady decline to 0, followed by the reversal with a steady rise in negative voltage from 0 to the maximum voltage, and a fall to 0 again.

Vibrating or oscillating currents of this kind are required to produce radio waves. However, the rate of vibration or oscillation, or the frequency, to use the radio term, must be of a much higher order than the 60-cycle frequency of lighting and power circuits.



Diagrammatic presentation of damped and undamped radio signals. The damped signals, shown in upper sketch, are in the form of rapidly damped out impulses, while the undamped or continuous wave signals are in the form of steadily maintained waves or oscillations.

Thus the 200-meter wave length of the usual amateur transmitter represents 1,500,000 cycles per second, while the 10,000-meter wave length of a high power station represents 30,000 cycles per second. It will be noted that the frequency or number of cycles per second determines the wave length, because the frequency accounts for the distance from one crest to the other of the radio wave. The radio frequency, in turn, is determined by two factors in either the transmitter or receiver—inductance and capacity.

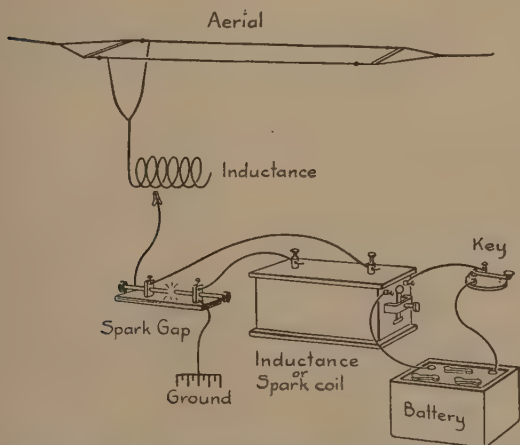
Inductance is the length of the conductor in a circuit, so far as the layman is concerned, and we must

keep to simple explanations in this work if we are to live up to its title. Thus if we have 100 feet of wire in a circuit we have four times as much inductance as in the same kind of wire 25 feet long. Inductance, for the sake of convenience and space limitations is generally arranged in the form of a spiral or a helix for the transmitter, using heavy conductor since the current to be handled is a powerful one. For receiving purpose, on the other hand, the inductance is in the form of insulated wire wound on tubes or wound in compact spools or coils for ready handling.

The capacity is the ability of a radio circuit or device to store electricity. Capacity can be introduced and controlled by a condenser, which is a reservoir or storage for electricity. The condenser is the only true reservoir for electricity, in that it returns practically all the energy that has been stored in it. The storage battery, on the other hand, is something quite different, although it also serves to store electricity. It accomplishes this end by causing certain chemical changes as it is being charged, and these chemical changes when reversed generate electric current which may be drawn from the battery until the chemistry of the battery is back to the original or discharged state. Thus the electric current is not stored. It is used to bring about chemical changes. The electric current drawn from the storage battery is not at all the same current that was used for the charging operation. However, for all practical purposes the storage battery is the only available reservoir of electricity we have today.

The condenser is made up of sheets of brass, aluminum, copper or tinfoil, separated by some non-conductor known as the dielectric. A number of metallic sheets are connected to one side of a circuit, while the same number of metallic sheets are connected to the other side. The non-conducting material or dielectric

separates the metallic sheets, or "plates." Between the plates of the condenser there is created a static or stationary electric pressure or charge, as distinguished from flowing electric current. This static pressure accumulates until the condenser, no longer capable of absorbing more energy, is fully charged. By connect-



The essentials of a radio telegraph transmitter, comprising a spark coil, aerial, ground, spark gap, key, and battery, as well as an inductance for tuning purposes.

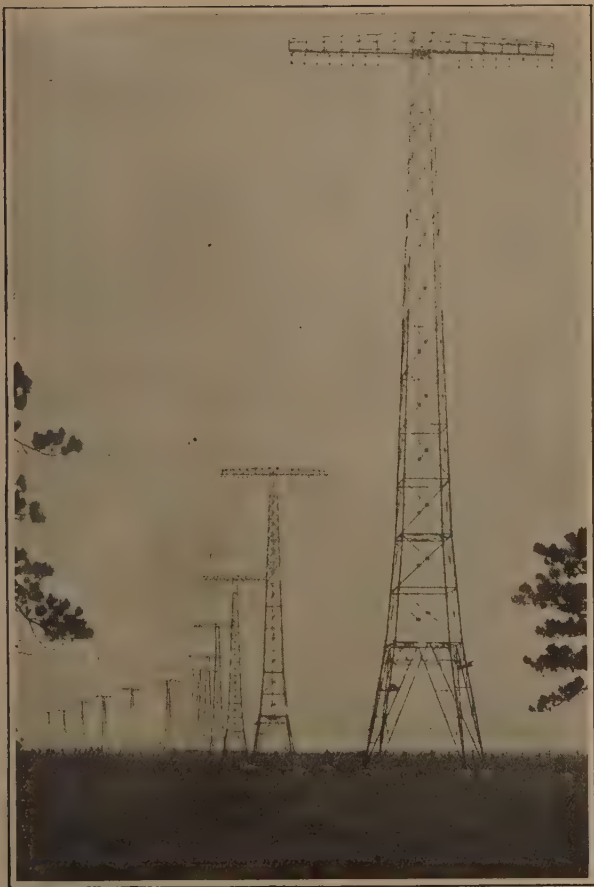
ing the two sides of the condenser the accumulated charge is immediately discharged, and the condenser returns to its original state.

Now let us suppose that the condenser is placed in a circuit which will charge it, and furthermore, let us place a spark gap across the condenser. The spark gap is nothing more than two conductors separated

by a slight air gap, across which a high-voltage electric current or charge will jump in the form of a spark. We begin charging the condenser, which absorbs the energy. Finally, the charge in the condenser becomes so great that it breaks down the resistance of the spark gap placed across the condenser. A spark jumps the gap. Just one fat spark is noticed, but something of considerable importance has taken place in that short interval of time. First, the condenser discharged itself, which means that the positive and negative charges on opposite sides exchanged places, recharging the condenser in the opposite direction, only to discharge again so as to restore the original polarity, and discharging again in the opposite direction, and so on, each reversal being weaker until the energy has been completely used up and the condenser is fully discharged. All this takes place in a fraction of a second. The discharge of the condenser is much the same as the swings of a free pendulum, which swings from side to side, each time getting weaker and weaker until it rests at zero. Thus the discharge of the condenser sets up an oscillating or vibratory current, which is the basis of radio waves.

THE ANTENNA OR AERIAL

Let us return for a moment to our pond of still water. Instead of a stone, let us use a hinged paddle which can be moved back and forth to create the waves. This paddle then becomes the agency for transferring power to the water, which is the medium for distributing the energy or power in the form of waves. In radio the energy for creating the radio waves is produced by the transmitter, while a system of insulated and elevated wires forming what is known as the aerial, serves to impart the energy to space in the form of radio waves.



The aerial and huge steel towers of a high-power radio transmitting station now employed for linking up the United States with the nations of Europe.

An aerial or, as it is more popularly called in the case of the receiving end of radio, an antenna, is employed at the receiving end to intercept the waves and bring the energy down to the receiving set. The receiving antenna may be likened to a second hinged paddle in our pool, placed at some remote point from the first paddle creating the waves in the water. The receiving paddle is provided with a bell. As the waves travel over the pond and finally reach the receiving paddle, they cause the paddle to sway and this action, in turn, rings the bell. This action is precisely parallel to the action of the radio antenna and the radio receiver.

Aside from the aerial or the antenna, a ground connection is required in radio communication. The ground side means a good connection with any object that runs into the ground, such as a water pipe, gas pipe or waste pipe, or even some object which is eventually connected with the ground, such as a steam-heating pipe. In the country, where such pipes are not available, a good ground may be secured by fastening a wire to a metal bucket which is dropped into a well or other body of water. Again, an iron rod may be driven down into moist soil. However, the securing of a good ground, as well as the construction of the aerial or antenna, is reserved for other chapters.

In reality, the aerial and the ground of a radio station form a condenser. The aerial and the ground are the plates of the condenser, while the air space between is the dielectric. To create radio waves it is necessary to have two "plates" separated by a distance of from ten to several hundred feet, and to create between them an electro-static pressure which changes its direction first toward one "plate" and then toward the other. In short, we have the discharge of a condenser, as already outlined, with the surging discharge setting up the desired oscillations. The charge must

change direction several thousand times per second to create radio waves.

The usual aerial of the transmitting station, and the ground connection, afford just such an arrangement. Between these "plates" we create an electro-static pressure of from one to 20,000 volts by means of a suitable transmitting equipment, which starts waves radiating in all directions. These pressure waves, as they are called, are only part of the radio waves. From any wire in which electric current is flowing, electro-magnetic waves are radiated; therefore, radio waves are made up of both electro-magnetic and pressure electro-static waves. The creation of these waves may be compared once more to the hurling of a stone into that hard-worked pond of ours. The amperes (the measure of current flow) put into the aerial corresponds to the size of the stone, while the volts (the pressure or potential of the electric current) are equivalent to the force with which the stone is hurled. The larger the stone and the greater the force behind it, the bigger the splash and the consequent waves. The more amperes of current flowing in the aerial circuit and the greater the pressure in volts between the aerial and the ground, the stronger the waves radiated and the farther they will travel.

THE ELEMENTS OF RADIO COMMUNICATION

So far, so good. In order to make use of radio waves for the practical purpose of sending messages and receiving them at a distant point, it is necessary:

(a) To produce regular electrical disturbances in a circuit, which starts the waves. These disturbances are electric currents which reverse rapidly in direction or vibrate, so to speak. In radio parlance this characteristic is known as oscillating, and we speak of transmitting circuits as oscillating circuits, and of trans-

mitters as oscillators. The rapidity of the reversal determines the wave length, as we have already learned.

(b) To get the waves into surrounding space, through which they travel at great speed. This is done by means of the transmitting aerial, which will be described further on.

(c) By means of these waves, to set up electric currents in a receiving circuit at a distant point. The device which these waves strike as they come in, and which turns them over to the receiving circuit, is called the wave-intercepting system, comprised of the receiving antenna or aerial, together with the ground connection. The latest sets make use of a few turns of wire constituting a "loop," which takes the place of the antenna and ground as the wave-intercepting system.

(d) To change these currents so that they may be detected by suitable apparatus. The operator usually receives the messages through sounds in a telephone receiver or loud-speaker.

There are several practical ways in which radio waves may be set up. The simplest consists of a spark coil, such as the type employed in the Ford ignition system; a condenser, represented by the aerial and the ground, and a spark gap as shown in the diagram on page 53. The spark coil has two windings, namely, a primary and a secondary. To the primary coil, which consists of a relatively small number of turns of wire wound about the iron core of the coil, are connected the battery supplying the initial current, and the vibrator or interrupter, which intermittently breaks the current flow from the battery. The secondary consists of a large number of turns of wire wound over the primary winding. In the nature of electrical happenings, when current is passed through the primary of such a combination, a high-voltage current is produced in the secondary winding. The primary cur-

rent may be only six volts, but the secondary winding produces a current with a potential of thousands of volts. This stepping up of current is a necessary part of radio transmission. Transformers are larger devices of this same general nature, employed in regular radio work.

The interrupter of the spark coil causes the secondary current to flow first in one direction and then in the other, as the primary current is interrupted. The secondary current, flowing for a moment in one direction, charges the condenser which is made up of the aerial and the ground. The capacity of this condenser is limited, and when it has been charged to overflowing, it releases its energy which jumps the spark gap in the form of a fat spark, only to pile up the energy on the other side of the condenser. Again the condenser is filled to overflowing, and it discharges once more, this time causing the current to flow in a direction opposite to that of the first time, and again the condenser is charged. Thus the discharges take place back and forth, but far faster than it takes to explain their action here. Indeed, the discharges travel back and forth with the speed of light, but gradually diminish in strength until the charge is exhausted. A series of such discharges constitutes a "train" of damped waves. Every time the vibrator or interrupter in the primary circuit makes and breaks the current in the primary, one of these trains is started. Since they die down rapidly, they are known as damped waves. Each one of these trains produces a single tick in the distant receiving station ear 'phones or loud-speaker, and it is the rapidity with which the trains or ticks follow one another that distinguishes one "spark" or tone of so-called spark or undamped type of radio telegraph transmitter from another. If we increase the capacity or the inductance in the transmitting circuit, we increase the wave length.

There is another type of radio telegraph transmitter known as the undamped or continuous-wave (CW for short) which operates on a different principle to be described further on. This type produces a flute-like note in the receiving 'phone or loud-speaker, broken into dots and dashes.

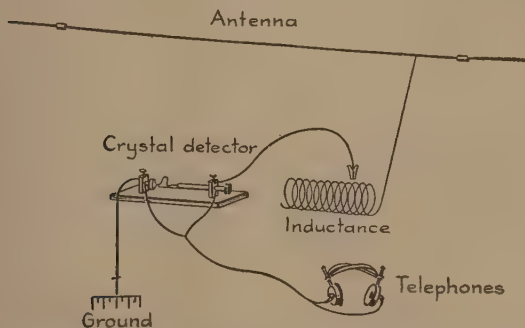
In actual practice the transmitter is connected to the aerial and ground. The oscillations charge the aerial and the ground, which act as a huge condenser. The longer the aerial, the longer the wave length of the aerial. This is known as the natural wave length of the aerial, as distinguished from what the transmitting wave length may be as the result of adding to the aerial wave length by means of auxiliary inductance, or taking away from its wave length by what is known as a series condenser.

HOW RADIO WAVES ARE RECEIVED

The radio waves are intercepted at any point within range of the transmitting station. Obviously, the waves become weaker as they travel out from the transmitter. A short distance away the waves may be intercepted by an inexpensive and relatively simple receiving set; but at a greater distance, when the waves are considerably weaker, a more elaborate and more expensive receiving set must be employed.

For receiving the waves, an antenna and a ground connection are usually employed. The first step is to tune the antenna-ground circuit so as to bring it in harmony or tune with the desired waves. When this is done, the intercepted waves flow down from the antenna to the ground. They may be diverted into suitable receiving apparatus by the simple arrangement shown in the accompanying illustration. However, even when they are diverted in this manner these wave energies are of frequencies of the order of several hun-

dred thousand cycles, and will not produce any sounds in the usual telephone receiver because they are beyond the range of audibility. But we recall that these waves are in the form of trains or groups. By making use of a device that can convert these trains or groups into direct current—current flowing in one direction—



The essentials of a radio receiving set, comprising the antenna, inductance coil for tuning, crystal detector, telephones, and the ground.

we secure a series of impulses flowing in one direction. The device which accomplishes this purpose is known as the detector. The current flowing from the detector to the telephone receiver is smoothed out into single impulses for each train, and these impulses are at a frequency well within the range of the telephone receiver which now produces audible signals.

In the case of undamped or continuous waves, which are produced in a different manner to be explained later, the intercepted waves even after conversion to direct current by the detector are virtually silent in the telephone receiver or loud-speaker. However, any

variation in these waves is present in the direct current output of the detector and is heard by the operator. This accounts for the radio telephone, which makes use of continuous waves to carry the sound values in the form of variations of those carrier waves. When the receiving set is tuned in for the carrier waves, little or nothing is heard until the carrier waves are varied at the transmitting end by the studio microphone.

RADIO SYMBOLS AND HOW TO READ THEM

The arrangement of the various instruments to form a radio transmitter or receiver is known as the hook-up. In order to simplify the presentation of a hook-up, various instruments are represented by simple symbols which have come to be standardized in all radio hook-up diagrams. Thus in showing the arrangement for a certain circuit, it is quite unnecessary to represent each instrument by a sketch of that particular instrument; instead, the appropriate symbol is used.

At first the layman may be somewhat confused and even frightened by the rather technical appearance of a radio diagram, but with very little application he can master the symbols and get to read the usual radio hook-up with just as much facility as though the actual instruments were shown instead of their symbols.

In the accompanying chart we present the more common radio symbols. A little study of these symbols will soon familiarize anyone with the essentials of radio hook-ups.

And having mastered the symbols, the layman should learn the most common terms employed in everyday radio work, as follows:

Aerial (Abbreviated A): One or more wires insulated from and suspended at more or less height above the ground. The aerial is employed to radiate energy

Alternator			Grid leak and Condenser	
Ammeter			Inductance	
Aerial		or 	Variable Inductance	
Arc			Key	
Battery			Resistance	
Buzzer			Variable resistance	
Condenser		or 	Single pole Switches Single throw	
Variable Condenser			Single pole Double throw	
Connection of wires			Double pole Single throw	
No connection			Double pole Double throw	
Coupled coils			Reversing	
Variable coupling			Telephone Receiver	
Detector			Telephone Transmitter	
Galvanometer			Transformer	
Gap, plain			Vacuum Tube	
Gap, quenched			Variometer	
Generator, D.C.			Voltmeter	
Ground				

Some of the more common radio symbols employed in radio diagrams.

in the form of radio waves produced by the transmitter. When employed for receiving purposes, the correct name for this member is antenna, although both terms are used interchangeably for either reception or transmission.

Alternating Current (Abbreviated A.C.): An electric current whose direction of flow is constantly changing during a period of time. Thus when we speak of a 60-cycle alternating current, we mean one that completely reverses its direction of flow sixty times per second. Alternating current plays a prominent part in many phases of the radio art.

Ammeter (Abbreviated Am.): An instrument used for measuring the flow of current in amperes through a given circuit. An ammeter is invariably connected in series with a circuit, so that the current must flow through it as well as through the circuit. Sometimes the current is passed through a heavy conductor placed across the ammeter proper, such a conductor being known as a shunt. A shunt permits of handling heavier currents than could be withstood by the ammeter winding.

Ampere (Abbreviated Amp.): The standard electrical unit of current flow.

Ampere-Hour: A unit of quantity of electrical energy, represented by one ampere flowing for one hour, or the equivalent. This term is generally used in expressing storage battery ratings. Thus a 60-ampere-hour battery is one which will deliver one ampere for 60 hours, 6 amperes for ten hours, or any variation of that statement.

Amplifier: This term is used in referring to either an amplifier tube or an amplifier unit. It is the device that serves to build up or magnify the radio energy or the audio or sound currents in a radio receiving set. There are two general classes of amplifiers: the radio-frequency amplifiers, which build up the radio

energy that is intercepted and then pass it on to the detector; and the audio-frequency amplifiers, which build up the audio-frequency energy or sound-producing current passed on by the detector. In many of the present-day receivers both classes of amplification are used. Furthermore, there is still a third class known as power amplification, which has to do with the building up of audio-frequency energy for loud-speaker reproduction.

Antenna: See Aerial.

Aperiodic: Without definite wave length. Thus a tuning member which is not tuned but is left as it is becomes an aperiodic member. Aperiodic coils are used in circuits to simplify the operation.

Arc: The passage of electricity through a gas, such passage depending on the volatilization of one or both electrodes. The electric arc can be employed for the generation of radio waves. In fact, it was used in the earlier radio telephone development, and is still used for continuous-wave radio telegraphy.

Armstrong Circuit: The original Armstrong circuit is the present-day regenerative circuit, which is still in wide use. See Regenerative Circuit. Since introducing that circuit, Major Armstrong has introduced several other circuits which have made his name still more famous in radio. He has given us the super-regenerative circuit and the super-heterodyne, both described elsewhere.

Atmospherics: Also known as static, strays, X's, "The noises of space." Natural electrical discharges occurring in the ether and in reality miniature lightning storms. Some authorities claim that static is due to sun spots. Whatever may be their genesis, since these disturbances travel through the same medium as radio waves they are readily picked up by receivers and prove very troublesome at times. It is impossible

to tune out these disturbances, for they have no definite wave length.

Audio Frequencies (Abbreviated AF): Frequencies corresponding to vibrations which are normally audible to the human ear. All frequencies below 10,000 cycles per second are termed audio frequencies. (See radio frequencies.)

Audion: A three-element vacuum tube. This was the name originally given to the three-element tube by its inventor, Dr. Lee DeForest.

Battery: Two or more electric cells connected together in a unit.

B Battery: The battery used for supplying the "plate" current for a vacuum tube circuit. This battery is made up of a large number of small dry cells, as a general rule, although there are storage batteries for this purpose. The usual B Battery has a rating anywhere from $22\frac{1}{2}$ to 150 volts.

Beats: Periodic effect produced by the difference between two vibrations thrown into interference. A simple case of the beat phenomenon is to listen to two clocks. Each clock maintains a uniform ticking, but the tickings of both clocks are not the same. However, every so often the tickings of both clocks come into perfect step, and then a loud combined ticking is heard, fading off into the two distinct tickings again, and so on. The loud ticking of the two clocks in step is the beat note effect.

Bridging Condenser: A condenser employed in a circuit for the purpose of providing a low impedance path for high-frequency currents across low-frequency apparatus. Also called a by-pass condenser. Typical of bridging condensers is the condenser sometimes placed across the usual telephone receivers.

Broadcasting: As applied to radio work, this stands for the simultaneous sending of intelligence either by radio telegraphy or telephony from a given central

point for the benefit of a large number of receiving stations located within the broadcasting station's range.

Buzzer: Device employed to generate electro-magnetic waves in a circuit for the purpose of testing the sensitiveness of a crystal detector.

By-Pass Condenser: See Bridging Condenser.

C-Battery: A small battery of 3 to 10 volts, depending on its particular application, which is inserted in the grid-return lead of a vacuum tube, with the minus pole towards the grid. The amplification of a tube can be materially increased by the careful adjustment of the amplifier potentials. Since the amplifier operates on the principle of grid voltage control, the plate of the tube must be maintained positive in order that the electrons emitted by the filament will flow to the plate. The grid must be maintained negative. When voltages over 50 are used on the plate, the grid becomes less effectively negative and current flows from the filament to the grid. This produces a voltage drop from the grid to the filament, which reduces the voltage effective for amplification. In order that the grid may be maintained negative, a dry battery of as low as 1 volt and as high as 12 volts should be used as a so-called C-battery.

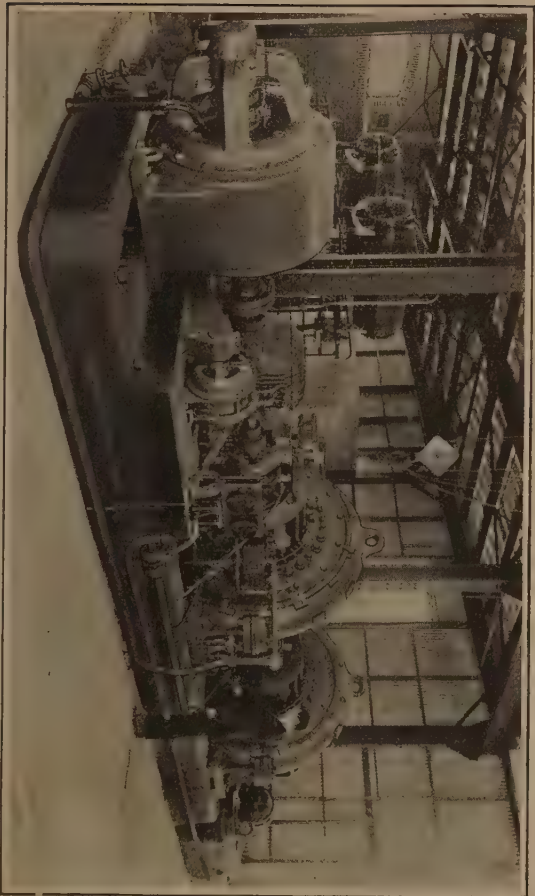
Capacity (Abbreviated C): Capacity as used in radio work plays a very important part. Capacity is the ability of anything to hold a charge of electricity. Thus there is capacity in parallel wires, in the aerial and ground systems, and so on. An instrument known as the condenser serves to introduce capacity in any circuit. The unit of electrical capacity is the Farad, but the farad being too large for practical radio work, the micro-farad (abbreviated mfd.—one millionth of a farad) is used. Thus we speak of a receiving condenser having a capacity of .001 mfd., or one thousandth part of a microfarad.

Cascade Amplification: This term refers to high amplification of received radio signals, wherein several vacuum tubes are employed in cascade or series fashion so that each one amplifies the radio or audio energy, as the case may be, and passes it on to the next in greatly increased volume.

Choke Coil: A coil wound to produce a great self-induction or choking effect when in the path of alternating current. Choking action when introduced in a radio circuit is called impedance. A choke coil is also known as a reactance coil.

Circuit: In radio and electrical work the path in which an electric current flows is called a circuit. A circuit may be open or closed or oscillating or shorted. If "open," it implies that the circuit is not completed; there is a gap somewhere, which prevents the current from flowing in the regular manner. If "closed," it implies that the circuit is completed, and current is flowing in the regular manner. If "oscillating," it implies that the circuit is such as to permit of oscillating currents—currents that surge back and forth. If "shorted," it implies that the circuit has a short cut somewhere which permits the current to return to its source before it has made the complete round of the circuit.

Close-Coupling: A tuning coil, set of coils, or transformer is said to be close-coupled when the primary and the secondary are quite close together, thereby causing much mutual inductance. Coupling permits of the transfer of energy from one circuit to another. Therefore, the closer the coupling the greater the transference of energy and the interplay of the circuits. The primary of any coupler or transformer device is the winding which carries the initial current; the secondary is the winding which receives its energy from the primary. In a receiving set coupler the pri-



High-frequency alternator for generating the energy required in projecting the radio dots and dashes across the Atlantic ocean. This alternator, of 200-kilowatt capacity, energizes an aerial measuring over $1\frac{1}{2}$ miles in length, supported by six 410-foot towers.

mary is usually connected to the antenna and ground, and the secondary is connected with the detector circuit.

Continuous Wave (Abbreviated C.W.): A form of electro-magnetic wave used extensively in radio work. C.W. waves have a constant amplitude or crest and therefore there is no damping effect, as distinguished from discontinuous or damped waves which are rapidly damped out. C.W. makes possible long-distance amateur radio telegraphy, not to mention commercial work. It is indispensable in the transmission of radio telephony.

Counterpoise: One or more wires stretched immediately above the ground but insulated from the ground. The counterpoise wires are usually directly beneath the regular aerial. This device is employed in transmission and reception when a good ground connection is not available. The counterpoise arrangement is employed in aircraft radio installations, where a ground connection is obviously out of the question. The aerial of an aircraft radio consists of one or more long trailing wires that are reeled up when a landing is to be made. The counterpoise, on the other hand, consists of the metallic parts of the aircraft, together with all the guy wires. The counterpoise arrangement is also employed in continuous wave transmission, where it is essential that the conditions be rigidly maintained.

Coupler: A device for transferring radio energy from one circuit to another. Ordinarily, the primary winding of the coupler is connected with the antenna and ground, while the secondary is connected with the detector. Couplers are also employed in coupling various radio circuits together. There are several types of couplers, the most common being the present-day vario-coupler, in which one winding rotates within a fixed outer winding. There is also the old-fashioned

loose-coupler, with the primary and secondary windings on separate tubes, one sliding within the other.

Coupling: The means for transferring electro-magnetic energy from one circuit to another. (See Close-Coupling and Loose-Coupling, and Coupler.)

Crystal Detector: Certain metallic crystals when introduced in a radio receiving circuit have the property of rectifying the incoming signal oscillations, which are high-frequency alternating currents, into direct current, so that the resultant or fluctuating direct current will operate a sensitive telephone receiver.

Cycle: The complete reversal of the current in an alternating current circuit.

Damped Waves: Radio waves which rapidly die out, instead of persisting as in the case of continuous waves. Damped waves start out with a high amplitude, but the amplitude rapidly drops off to zero. The usual spark transmitter employed in dot-dash communication is generally of the damped-wave type.

Detector: Any apparatus which transforms the oscillations received by the antenna-ground circuit into audible currents or transfers the characteristics of the radio waves to a locally generated direct current which will actuate a telephone receiver. The most common types of detector in regular use are the crystal detector and the vacuum tube detector.

Dielectric: A material that offers a very high resistance to the flow of electric current. Practically, we would say that a dielectric does not conduct current, but theoretically there is no such thing as an absolute non-conductor. The dielectric in a condenser is that material which separates the two sides of the condenser. In the usual variable plate condenser, the dielectric is the air between the plates.

Duo-Lateral Coils: Special form of compact inductance coils which derive their name from their characteristic winding.

Direct Current (Abbreviated D.C.): An electric current flowing continuously in one direction. In a two-wire circuit, for example, direct current always flows from the positive source to the negative return. Therefore, direct current always has a readily determinable polarity, while alternating current (abbreviated A.C.) which is constantly reversing its polarity while flowing through a circuit, has no apparent polarity.

Electrolyte: The active liquid of a battery. In the case of the usual storage battery, the electrolyte consists of sulphuric acid diluted in distilled water.

Electro-Magnet: A temporary magnet which is energized by the passage of an electric current through its winding. An electro-magnet consists of a soft-iron core about which are placed many turns of wire to form a winding.

Electron: The ultimate particle of negative electricity, which plays a fundamental part in the constitution of matter as well as in the electric current. Radio-active emanations, electric discharges, and so on consist of streams of electrons, ejected at immense velocities from the atoms of which they formed part; and ordinary electric currents are in some way an electronic phenomenon.

Electro-Motive-Force (Abbreviated E.M.F.): The electrical pressure or potential, the unit of which is the volt.

Electro-Static: Relating to an electrically charged body in which no current flows. Electro-magnetic energy is that which has to do with flowing current and with its magnetic effects. Electro-static energy has to do with static or stationary electricity which exists as charges of electricity.

Ether: A hypothetical medium of great elasticity and extreme minuteness, supposed to pervade all space as well as the interior of solid bodies. It is the medium through which light, heat and radio waves have here-

tofore been said to be transmitted. The Einstein theories have shattered the ether theory for the moment, however, although many radio men still cling to it as a convenient way of explaining radio communication.

Farad: The unit of electrical capacity. (See Capacity.)

Feed-Back: The energy returned from the plate circuit to the grid of the vacuum tube, and the means for returning it in a regenerative circuit. The feed-back control is usually called the "tickler," and is labeled the "intensity" or "volume" control in the radio broadcast receivers.

Filament (Abbreviated F): The hot element in the vacuum tube, which emits the electrons.

Flat-Top Aerial: One whose suspended wires are stretched parallel to the earth.

Frequency: In alternating currents, the rapid reversal of the current through a circuit. Thus we speak of a frequency of 60 cycles, which means that there are 60 complete reversals or cycles per second. (See Alternating Current, Audio Frequency and Radio Frequencies.)

Generator: A machine that converts mechanical energy into electrical energy.

Grid (Abbreviated G): The control member in the three-element or standard vacuum tube. The grid is generally in the form of a round or flattened spiral, or as a zigzag length of wire, or again it may be a lattice-shaped stamping. The grid is placed between the hot filament and the cold plate or positive member. The grid regulates the electronic flow from the hot filament to the cold plate.

Grid Bias: A negative potential applied to the grid of the detector or the amplifier tube. This is usually accomplished by means of a potentiometer placed across the filament, with its movable contact connected

with the lead from the tuner if dealing with a detector, or the lead from the transformer, if dealing with an amplifier.

Grid Leak: A very high, non-inductive resistance connected across the grid condenser or between the grid and the filament of a vacuum tube serving as a detector, in order to permit excessive electrical charges to leak off to an external source, thus furnishing stable control under all operating conditions.

Ground (Abbreviated G): In radio work the ground is the counter-part of the aerial or antenna. It functions in connection with the aerial or antenna in the transmission or reception of radio waves. The term "ground" is used to imply any connection with the ground, whether through a water pipe, gas pipe, steam pipe or other means. On shipboard the ground is a connection with the steel plating of the hull. (See Counterpoise.)

Harmonics: In radio, harmonics refer to the incidental waves mostly noticeable in undamped or C.W. wave operation. These harmonics differ in wave length or frequency from the true or original operative wave. The first harmonic is three times that of the true frequency, or one-third the wave length of the aerial; the second harmonic is five times the true frequency or one-fifth the wave length; the third harmonic is seven times the true frequency, or one-seventh the wave length. At times, amateurs will hear the harmonics of high-power long-wave stations, even though the amateur receiver may be set for much shorter wave length. This also accounts for the reception of some radio broadcasting stations at two entirely different adjustments of the receiving tuner.

Henry: The unit of Inductance.

Hertzian Waves: Electro-magnetic waves named after their discoverer, Prof. Heinrich Hertz, in 1887.

These waves are the basis of our present radio communication.

Heterodyne: The production of the phenomenon of "beats" in radio work, brought about by playing off one continuous wave energy against another and thus obtaining a beat note corresponding to the difference between the two continuous wave frequencies. The heterodyne effect is well known in radio work of all kinds. If one is listening to a station and suddenly some other listener-in within a short distance tunes in that same station and then proceeds to force his regenerative receiver, a bird-like whistle will be heard in one's set. This whistle is the heterodyne effect produced by the difference in frequency between the radio transmitter wave and the weak wave sent out by the regenerative receiver. Or if one's own regenerative receiver is allowed to oscillate, by being forced, a whistle or howl will be heard, due to the beat note of the heterodyning of the local oscillations and the incoming wave. Indeed, continuous-wave telegraph signals are received by producing a local continuous-wave frequency that is sufficiently different from the incoming continuous-wave energy to produce an audible beat note.

Honeycomb Coils: Compact inductance coils which receive their name from their characteristic winding.

Hook-Up: A diagram showing the connections or the wiring for a radio receiver or transmitter. Diagrams of this kind make use of conventional radio symbols to represent the various pieces of apparatus.

Hydrometer: An instrument for measuring the specific gravity or density of liquids. In radio work the hydrometer is used to test the storage battery electrolyte.

Interrupted Continuous Waves (Abbreviated I. C. W.): In undamped or continuous wave transmission

of the dots and dashes of the telegraph code, it is sometimes desirable to break up or interrupt at an audible rate the continuous waves so that they may be received by anyone without the necessity of heterodyning or other special arrangements at the receiving end. This is known as interrupted continuous wave transmission.

Hot-Wire Ammeter: An instrument used in radio transmission and in measuring work for measuring radio energy in amperes or milli-amperes, by means of a wire that expands in proportion to the heat generated by the energy passing through it, this hot wire being linked with the indicating needle.

Impedance: This is the term applied to the resistance offered by a coil of wire to current flowing through it due to the counter-electromotive pressure, irrespective of the actual resistance of the conductor in ohms. Counter-electromotive pressure is developed in certain forms of inductance, and this counteracts the flow of current.

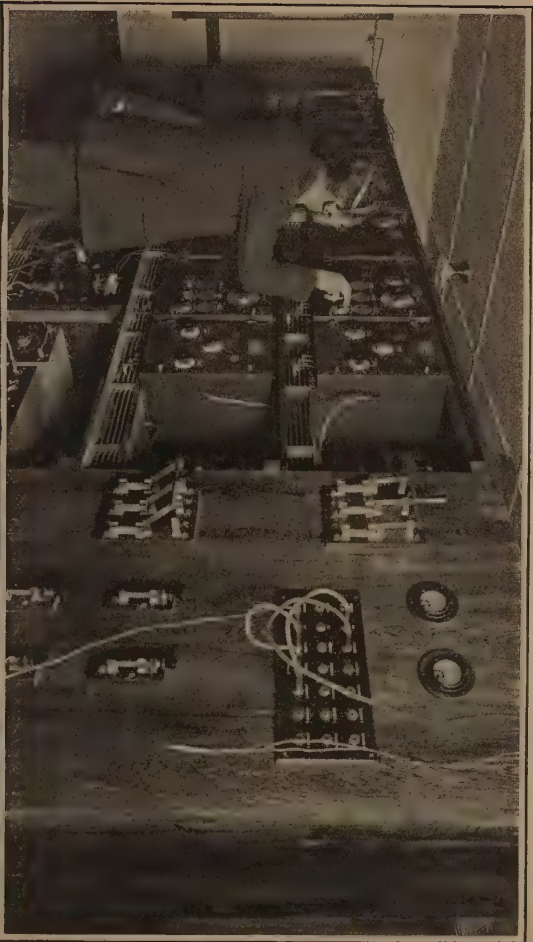
Inductance (Abbreviated L): Like capacity, inductance plays a very important rôle in radio circuits. It is the transfer of an electric or magnetic energy from an electrified or magnetized body to a non-electrified or non-magnetized body by close proximity but without actual contact. The unit of inductance is the Henry. In radio work the mil-henry and the micro-henry are the terms generally used.

Insulator: A non-conductor of electricity in the practical sense.

Interference: Any electrical disturbance which originates outside the radio receiver and which interferes with the proper reception of signals.

Interrupter: A device for intermittently breaking or interrupting an electric current.

Jack: Device which receives a handy connecting device known as the plug. The jack can also be ar-



Part of the receiving equipment of a trans-Atlantic radio station. This receiving equipment is located some 70 miles distant from the actual operating room, a telephone line joining the operators with the remote receiving equipment.

ranged to control circuits with the insertion and withdrawal of the jack.

Key: A form of switch that serves to make and break a circuit for the purpose of producing the dots and dashes of the telegraph code.

Kilocycle: 1000 cycles.

Kilowatt (Abbreviated KW.): One thousand watts. A unit used in measuring large amounts of electricity.

Lead: A wire from one instrument to another.

Lead-In: The wire or cable that connects the aerial or antenna with the radio equipment.

Loading Coil: An inductance inserted in a circuit for raising the wave length of that circuit, yet is not coupled to any other coil.

Loop: A substitute for the usual antenna and ground, in the form of a number of turns of wire on a wooden or hard rubber frame. Because of the ultra-sensitive receiving apparatus now in use, it becomes possible to use a small loop, say two-foot square, for intercepting long-distance radio broadcast waves instead of the usual antenna and ground arrangement.

Loose-Coupler (Abbreviated LC): See Coupler.

Loose-Coupling: The opposite of Close Coupling.

Loud-Speaker (Abbreviated LS): Any device designed to reproduce signals loud enough to be heard without the use of head-phones.

Megohm (Abbreviated Meg.): One million ohms. This is a convenient term for rating grid leaks.

Microfarad (Abbreviated mfd.): One millionth part of a farad, and the practical unit of capacity.

Microphone: Device for converting sounds into their electrical equivalents. The microphone causes certain variations in the flow of electric current. It is the instrument used in both wire and radio telephony. The most common type of microphone consists of a diaphragm which is actuated by the sound waves that strike it, the vibrating diaphragm acting on a

mass of loosely packed carbon granules held between carbon blocks and subjected to more or less pressure, according to said sound waves.

Milliampere: The thousandth part of an ampere.

Millihenry: One thousandth of the unit henry.

Modulator: Device for varying the amplitude of one current in accordance with the variation in another current. It is a form of coupling device extensively employed in transmitting, whereby a relatively weak microphonic current can be caused to modulate or vary a powerful transmitting current.

Motor-Generator: A motor and generator combined in one unit, for the purpose of converting one kind of current into another. Thus the motor member can be made to operate on 110 volts direct current, and will drive the generator which will deliver 1,000 volts direct current.

Natural Frequency: The wave length of any aerial or circuit without the introduction of inductance or capacity devices.

Neutrodyne: A form of radio-frequency receiver of remarkable sensitiveness and simplicity of operation, deriving its name from the method used to neutralize the capacity existing between the grid and the plate of each vacuum tube.

Ohm: The unit of electrical resistance.

Ohm's Law: The fundamental law of electricity. It states that the current in amperes flowing through a circuit is equal to the pressure in volts divided by the resistance in ohms.

Oscillations: Alternating currents of very high frequencies are called electrical oscillations. If the amplitude of a series of oscillations is constant, the oscillations are producing continuous or undamped waves; but if the amplitude is not constant and is of a decaying nature, the oscillations are producing damped waves.

Plate (Abbreviated P.): The positive member or electrode in the vacuum tube. This member is generally in the form of a round cylinder or a flattened cylinder. Sometimes it is in the form of a flat electrode.

Potentiometer (Abbreviated Pot.): Resistance winding placed across a source of current and through which current is flowing, and provided with a movable contact. Any voltage or potential within the capacity of this resistance and the applied voltage can be obtained between one end of the potential winding and the movable contact.

Plug: Convenient form of connecting device, usually employed to connect head-phones or loud-speaker to the receiver.

Primary (Abbreviated P): The winding of a transformer or a coupler on which current is impressed.

Potential: Term applied to voltage or electrical pressure. (See Electromotive Force and Volt.)

Radiation: The transmission of energy through space in the form of electro-magnetic waves. By the radiation of a transmitter is meant the volume of high-frequency energy which is being delivered to the aerial for propagation in the form of waves.

Radio Frequencies (Abbreviated RF.): Frequencies corresponding to vibrations not normally audible to the human ear. All frequencies above 10,000 cycles per second are termed radio frequencies.

Reactance: See Impedance.

Reactance Coil: See Choke Coil.

Rectifier: Device for converting alternating current into pulses of direct current for the purpose of recharging storage batteries off alternating current supply. Certain metallic crystals possessing a rectifying action when used as detectors in receiving circuits, are also referred to as rectifiers.

Regenerative: See Feed-Back.

Regenerative Circuit: Also known as the Armstrong circuit, after its inventor. This circuit makes use of a vacuum tube as detector, so connected that after detection and rectification the signal introduced into the plate circuit is led back and caused to react upon the grid circuit, thereby increasing the original energy of the signal received by the grid and greatly amplifying the response to weak signals. In reception the leading back or feeding back of plate energy to the grid is generally accomplished by tuning the plate circuit or by inserting a coil in the plate circuit, and bringing this coil into inductive relation with a winding in the grid circuit. Either of these devices is known as the tickler.

Reflex: Using the same vacuum tubes first for radio-frequency amplification, and then, after detection, for audio-frequency amplification.

Resistance: Opposition to the flow of an electric current through a conducting medium. All metals have more or less electric resistance. Copper is used universally as a conductor for both radio and electrical work on account of its low resistance, comparatively low cost, and ready supply. Silver is a better conductor but is too expensive. Certain nickel alloys are employed when high resistance is required, such as in rheostats. The unit of resistance is the ohm.

Resonance: Resonance is another term for tuning. Resonance in a given circuit is said to exist when its frequency or tune has the same value as the frequency or tune of the alternating electromotive force introduced in it. The current is then in resonance or tune with the natural period of vibration of the circuit.

The theory of electrical resonance is the same as that of acoustics readily demonstrated by tuning forks, where one tuning fork will not respond to another unless it is of the same key or pitch. Bringing a cir-

cuit into resonance means bringing it into tune with another circuit or transmitter.

Rheostat (Abbreviated R): A variable resistance device usually employed to control or regulate current flow.

Rejector Circuit: See Wave Trap.

Relay: Device with which one circuit can be controlled by another.

Selectivity: The ability to select any particular wave length to the exclusion of others; the tuning accuracy.

Sharp Tuning: Where a very slight change in the tuner produces a marked effect in the strength of signals. The sharper the tuning, the greater the selectivity.

Secondary (Abbreviated S): The secondary winding of a transformer or coupler is the one that receives energy from the primary winding and delivers this energy to the secondary circuit.

Shunt: A by-pass arrangement or an instrument connected across another. When heavy currents are to be registered by an ammeter, a shunt is sometimes used across the delicate winding of the ammeter so that the greater part of the current flows through the shunt, while only a small amount passes through the ammeter to actuate it. Nevertheless, the ammeter is calibrated so as to allow for the passage of the current through the shunt.

Signals: Electrical energy that conveys intelligence. Even the radio telephone talks and musical features are referred to as signals in radio parlance.

Storage Battery: A battery that can be recharged from some source of electric current when necessary. A storage battery is often used to supply the necessary energy for the operation of the vacuum tubes.

Static: (See Atmospherics.)

Super-Audible: A frequency which lies above the range of audibility.

Super-Heterodyne: A method of receiving in which the incoming radio wave is played off against a locally generated frequency, producing a "beat" energy of super-audible character which can be efficiently amplified by untuned radio frequency amplifiers before passing through the detector, which converts it into the audio-frequency energy that is passed through one or two stages of audio-frequency amplification and then into the loud-speaker.

Super-Regenerative: A method of amplifying radio signals in which self-oscillation of the detector is prevented by periodically damping the circuit.

Tickler: Device, such as a coupling coil or a variometer, used to produce a feed-back or a regenerative effect.

Tikker: An interrupter used in certain receiving circuits to break up incoming CW signals and make them audible with the usual detector. However, with the regenerative receiver or with any receiver that can generate a local wave of a wide range of frequencies, a CW signal can be detected by the heterodyne effect.

Transformer: Device used in electrical and radio work for the transference of energy from one circuit to another, with or without change in the voltage, as desired. There are power transformers, amplifying transformers, telephone transformers, modulation transformers, oscillation transformers, and so on. All transformers have a primary and a secondary winding. The primary winding receives the initial energy, which is induced in the secondary at the same or a different voltage, depending on the ratio which the primary and the secondary windings bear to one another.

Tuner: That part of a circuit which is used to alter the wave length or tune of the circuit.

Tuning: The act of altering the capacity or induc-

tance values or both in a radio circuit, so as to bring the circuit into resonance with an external circuit or transmitter.

Undamped: A train of high-frequency oscillations of constant amplitude, such as continuous or CW waves.

Vacuum Tube (Abbreviated V.T.): A glass tube exhausted of air and containing essentially a filament which is heated for the creation of electrons; a plate, positively charged, to which the electrons are attracted; and a grid, consisting of a helix of fine wire, inserted between the filament and the plate for the purpose of controlling the amount of electronic flow. The vacuum tube plays four leading rôles in radio: detection, amplification, modulation, and generation.

Vario-Coupler (Abbreviated VC.): See Coupler.

Variometer (Abbreviated V.): An instrument that serves to vary the inductance and wave length of any circuit. It consists of a set of fixed windings and a set of rotatable windings, the latter fitting within the former. When both sets of coils are adjusted so that the current flows in the same direction in both, we have a maximum of inductance. When the current flows in opposite directions, due to turning the rotatable windings which are known as the rotor, the coils are said to be bucking each other and the inductance is at a minimum. Both windings are connected in series.

Velocity of Radio Waves: Radio, electricity and light waves travel through space at the speed of 186,300 miles per second.

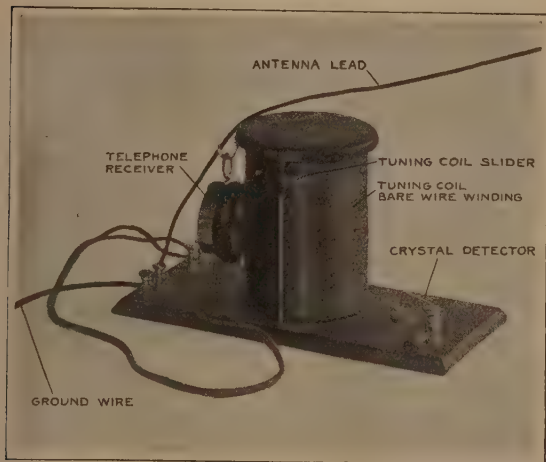
Vernier: Device for the finer adjustment of any given control. The vernier is generally an auxiliary control, which permits of delicate adjustments in between the usual receiving control adjustments.

Volt (Abbreviated V.): The unit of electric pressure.

Voltmeter (Abbreviated V.M.): An instrument for

measuring the voltage or pressure of a current flowing through an electric circuit.

Watt (Abbreviated W.): The unit of electric power. To find the electric power involved, multiply the volts by the amperes, obtaining the watts. 746 watts equals



Simplest type of radio receiving set, consisting of a tuning coil with sliding contact to vary wave length, a crystal detector, and a single telephone receiver.

one mechanical horsepower. 1,000 watts equals one kilowatt (KW).

Wave Length: Radio waves, in their passage through the conducting medium of space, travel in undulating wave form similar to the waves at the seashore. When the wind is blowing hard and steady the distance between each wave crest is comparatively long, while

if the wind is blowing more mildly and in short spurts, the distance between wave crests is accordingly shorter and we have short waves. In radio, substitute the transmitter for the wind and you have the same action. Wave length is, therefore, closely related to frequency, *i.e.*, long wave lengths have low natural frequencies, while short wave lengths have greater natural frequencies. Wave length is the distance from one wave crest to the next.

Wave Trap: Also known as rejector circuit. A circuit that can be tuned to any undesired signal so as to absorb that signal and prevent it from reaching the receiving set.

Wired Wireless: The use of radio transmitting and receiving apparatus in transmitting over conductors, such as electric power wires, telephone lines, and so on. Wired wireless has been aptly called "guided radio," while the usual radio is referred to as "un-guided radio."

The foregoing list by no means covers all the terms encountered in radio, but it covers the more common in such a manner as to give the layman a start.

CHAPTER III.

THE INTERCEPTION AND INTERPRETATION OF RADIO BROADCAST WAVES

THERE is nothing complicated about the interception and interpretation of radio broadcast waves—at least fundamentally. The apparatus, which is called the receiver or receiving set, may be of the simplest sort if the distance to be spanned is relatively small. Virtually no experience is required if a complete receiving set is used, for anyone can turn the few knobs and adjust the devices employed. No license is required, and anyone can and is entitled to intercept the radio programs without formality of any kind. Lastly, the cost is remarkably reasonable, considering the wonderful possibilities of a radio receiving set.

It is only when one desires to span great distances and to reproduce the radio programs with sufficient volume so as to fill a large room, night after night with fair regularity, that the cost mounts up. Even so, the cost is still no greater than that of a good phonograph, and certainly less than half the cost of a low-priced automobile. After all, it is a question of what is expected of the receiving equipment, and

successful results demand that the receiving equipment be fitted to the requirements.

ESSENTIALS OF RADIO RECEPTION

No matter how simple a receiving set may be and how modest the requirements, there are certain essentials that must be provided. Thus we have—

First: The wave-intercepting system, which usually comprises one or more wires elevated and properly insulated from the ground, known as the antenna or aerial, as well as the ground connection. The antenna type of wave-intercepting system serves to intercept the maximum amount of radio energy and therefore represents the maximum efficiency in radio interception. However, in view of the inconvenience of the usual antenna, especially as regards city dwellers, there has of late been a steadily increasing demand for the loop type of wave-intercepting system. The loop comprises a simple frame which holds a number of turns of wire, and serves to intercept the radio waves even though it is placed indoors, alongside the receiving set. Because of its diminutive dimensions, however, the loop does not begin to intercept the amount of radio energy of the usual antenna; accordingly, it is necessary to employ far more sensitive and elaborate receiving apparatus with such a wave-intercepting system for given results. The ends of the loop winding are connected to the receiving set, and no ground connection is required.

Second: A means of altering the wave length of the wave-intercepting system and of the allied receiving circuits, so as to intercept and detect any desired radio waves to the more or less complete exclusion of undesirable waves. This process, known as tuning, is accomplished by the use of two factors, known as

inductance and capacity, as will be explained further on.

Third: A means of changing the character of the incoming radio energy of the radio waves from radio frequency to audio frequency, so that the latent sound values in the case of the radio telephone waves, or dots and dashes in the case of radio telegraph, can be reproduced with suitable sound-producing equipment. The instrument that accomplishes this result is known as the detector, of which there are two main types in general use, namely, the simple crystal detector and the vacuum tube detector.

Fourth: A device which takes the audio frequency current delivered by the detector and converts it into sound waves, so that we obtain a replica of the original sounds impressed on the radio waves, or the dots and dashes of the radio transmitter, as the case may be. This device may take the form of a telephone head set, which requires little energy for its operation and is therefore connected directly with the output of the detector. Again, this device may take the form of a loud-speaker, which requires considerable energy for its operation, so that it can fill a large room with the radio programs. The loud-speaker, requiring more energy than the detector alone is capable of delivering, calls for another factor known as the audio-frequency amplifier.

Fifth: The audio-frequency amplifier, which serves to magnify the weak output of the detector tube so that audio-frequency energy of the desired strength can be made available for the loud-speaker or even the telephone head set. The audio-frequency amplifier is introduced between the detector and the sound-reproducing device.

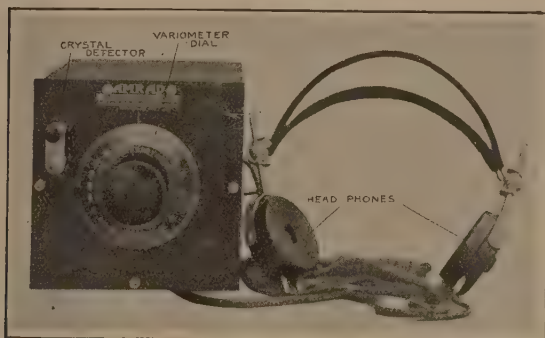
Sixth: When super-sensitiveness is desired for the receiving set, such as in reaching out over great spans, it becomes necessary to magnify the weak radio

energy which is passed on to the detector. The detector, after all, is very much like a gun in its operation. That is to say, it has a trigger action. The figurative trigger has to be pulled before the tube "goes off," and the trigger requires a certain amount of energy to actuate it. The consequence is that unless the radio energy is sufficient to "pull the trigger," so to speak, the tube will not "go off" and the signals will not be rectified by the detector and passed on to the head set or loud-speaker. So, as an additional factor in receiving we have what is known as radio-frequency amplification, which magnifies or amplifies or builds up the weak radio energy, no matter what its original strength may be, and passes it on to the detector in such volume as to set off the detector. Radio-frequency amplification must not be confused with audio-frequency amplification. The former strengthens the radio energy, and therefore the sensitiveness and the range of the receiving set. The latter strengthens the sounds reproduced by the head set or loud-speaker, but does not add to the basic sensitiveness or distance covered by the receiving set.

Seventh: The simplest method of obtaining radio-frequency amplification is by means of regeneration or feed-back control. By this is meant the feeding back of part of the plate energy of the detector tube to the grid of that tube, so as to strengthen the grid charge and thus, in turn, increase the plate energy. The sensitiveness of the detector and the volume of sound reproduction is enormously increased by the use of regeneration or feed-back control. Regeneration has been used for a long while back in radio receiving sets as a simple yet very effective method of radio-frequency amplification. Now, however, with the advent of low-current-consuming tubes and improved radio-frequency arrangements, the regenerative receiver is no longer as popular as it has been in the

past. However, regeneration is still used in more or less modified form as a factor in many of our elaborate multi-tube receivers.

Eighth: In order to economize on the number of vacuum tubes that are required for the various stages of audio-frequency and radio-frequency amplification, it is possible to make the same tube serve both func-



Simple crystal type receiving set, making use of a variometer as the tuning unit, a crystal detector, and a pair of headphones. The crystal type receiving set works well for short distances; indeed, the quality of its reception is unexcelled by any other type.

tions by a process of passing the radio energy through a given tube and then through the detector, followed by the return of the rectified or audio-frequency output of the detector to the same tube which then acts as an audio-frequency amplifier. This procedure is called reflexing, and a receiver incorporating such an idea is known as a reflex set or circuit.

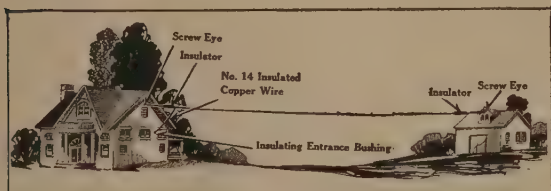
These essentials cover the entire range of receiving apparatus at the present stage of the radio art, despite the enormous variety of names for circuits which are all basically the same.

THE ANTENNA AND GROUND AS THE WAVE-INTERCEPTING
SYSTEM

The first step, then, is to consider the aerial or antenna for receiving purposes. While the same aerial or antenna may be used for both receiving and transmitting functions, as a general thing these functions are by no means interchangeable if really efficient results are desired. Thus the ideal antenna for receiving—antenna, by the way, is a happier term for the receiving end than aerial, the latter applying more properly to transmission work—is a single wire, insulated at both ends, elevated some 20 feet or more above the ground and measuring 125 feet or less in length. A shorter wire makes for lower efficiency, while a longer wire, strange as it may seem, also detracts from the receiving efficiency. The reason for this is that the wave length of the aerial should be as nearly as possible that of the radio waves to be intercepted. Otherwise, in the case of a shorter wire, it becomes necessary to add excessive inductance in order to bring up the wave length of the wave-intercepting system, and such excessive inductance means some loss of energy. Furthermore, a shorter wire will not intercept as much of the radio energy as a longer one. Now, on the other hand, a longer wire intercepts more of the radio energy, but it becomes necessary to use either a variable or fixed condenser in series with the antenna in order to bring down the wave length, and such practice means a loss of energy. Of course, we are considering the receiving set on the basis of amateur and radio broadcasting reception. If one desires to receive the dot-dash signals of long-wave commercial stations, a longer wire is quite satisfactory. Indeed, for the best kind of work it may be well to have several antennae, arranged for various classes of reception.

As for the wire and the arrangement of the antenna, these details are left for the chapter dealing with the installation of the receiving set. Suffice it to say here in the way of a general fact that there is considerable latitude in the arrangement of the antenna and the kind of wire used. In these days of powerful radio broadcasting stations, almost any system of insulated conductor and ground connection will function as a wave interceptor. Indeed, our present-day super-sensitive receivers work without ground or antenna at short distances.

The ground member of the wave intercepting sys-



General idea for the antenna of a receiving set. A single wire is used, insulated at both ends and suspended some distance above the ground. In the city the antenna wire may be placed between two poles on the roof of the house.

tem is nothing more than a connection with the ground through some suitable means. The effectiveness of the wave intercepting arrangement depends to a very great extent on the ground connection. The most practical ground connection is the water supply system, to which a good connection is made by means of a so-called ground clamp. Where this is not available, pipes connected with the heating or gas system, may be used, although these are to be regarded with some suspicion. Sometimes a non-conducting length of pipe is inserted in the gas line before it reaches the earth,

so that it is not a true "ground." However, the results obtained will soon disclose whether the pipe is grounded or not. Where such facilities are not available, there are other means of establishing a ground, which are explained in the chapter on installation of the receiving sets.

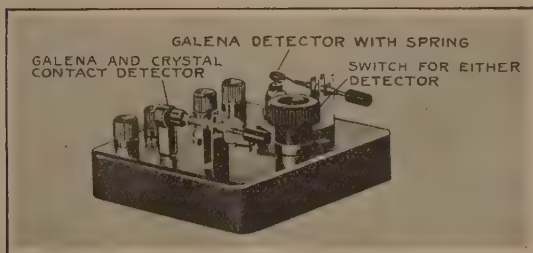
THE HANDY LOOP AS A WAVE-INTERCEPTOR

Because of the awkwardness of the antenna arrangement, especially in the crowded city apartment house, the roof of which may already be festooned with antennae of all kinds or, to deal in extremes, may be positively barren of any antennae because of the strenuous objections of the landlord to radio installations, there is a steadily growing demand for the loop type of wave interceptor. The loop is by no means as effective as an outdoor antenna, but its low efficiency is counteracted by the use of more sensitive receiving apparatus. A loop consists of a suitable wood, hard rubber, or composition frame on which are wound several turns of bare or insulated wire side by side to form a solenoid design, or one turn inside the other so as to form the helical design. The frame is suspended or mounted in such a manner as to permit of being swung in all directions. If rigidly mounted in the cabinet of a self-contained set, then the set must be turned about for the best reception. The loop receives best when it is pointing edge on towards the transmitter, and it is this characteristic of the loop which makes it so interesting. It indicates the direction of the transmitter being intercepted, and this forms the basis of the radio compass which has found such wide use in modern navigation.

In the chapter dealing with the installation of receivers, the subject of loops is dealt with at length.

THE IRREDUCIBLE MINIMUM IN RECEIVERS

With the wave-intercepting system accounted for, the next step is to consider the essentials of radio receiving equipment. The simplest receiver comprises a detector and a single telephone receiver. The detector, as we have already learned, is a device which changes the frequency of the incoming radio waves from radio frequency to audio frequency so that the



Crystal detector stand with two different kinds of crystal detector, one being of the "cat-whisker" type, with a fine wire resting on the crystal surface, and the other of the double crystal type, with two different crystals in contact with one another.

signals, whether they be dot-dash messages or music, may be heard in the telephone receiver.

Let us consider the simplest kind of detector. Nothing could be simpler or less expensive than the crystal detector. It makes use of one of several different kinds of mineral crystals which possess the desirable characteristic of current rectification. The most popular crystal body today is galena (lead sulphide), a silvery gray mineral which breaks into tiny squares with mirror-like surfaces. Resting on the galena crystal is a

fine piece of wire, known as the "cat whisker"; and it is the delicate contact between the crystal and the wire which rectifies the high-frequency radio energy ranging from 20,000 to 6,000,000 changes of direction per second, impulses of varying strength traveling in one direction only, and therefore capable of operating a telephone receiver. Sometimes another crystal is employed in contact with the galena, in place of the "cat whisker."

Now with all crystal detectors the matter of adjustment is an important one. Unfortunately, the crystals are not uniformly sensitive. Here and there on a given surface there are sensitive as well as "dead" spots, and the former must be sought. Hence when using a crystal detector the wire member must be shifted about on the surface of the crystal until a sensitive spot is located. Once a sensitive spot is found, the detector need not be adjusted for some time. However, if it is jarred the sensitive contact may be lost, and readjustment is then necessary.

While the crystal detector is far more sensitive than the earlier forms of detector employed during the pioneer days of radio communication, it is not nearly as efficient as the vacuum tube type. However, the crystal type is inexpensive and may be used with the simplest kind of equipment. It requires no batteries of any kind.

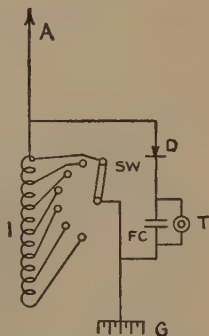
The simplest receiving set, therefore, consists of the antenna and ground—the loop cannot be used with the crystal detector, because insufficient energy is intercepted by the loop to operate the relatively insensitive detector—crystal detector and telephone receiver. No attempt is made to tune such an arrangement. At short distances from a powerful radio telephone or radio telegraph transmitter a crude receiving set of this kind serves quite nicely. Indeed, from France comes the little receiving set which may be carried

about in one's pocket. It comprises a telephone receiver on the back of which is mounted a crystal detector. Such an arrangement is used for intercepting powerful radio waves.

SIMPLICITY COMBINED WITH EFFICIENCY

With no provision made for tuning, a receiving set must perforce be of a low order of efficiency. Furthermore, all signals come in at the same time, if several transmitters are working in the immediate vicinity. By providing the simplest kind of tuning device, the efficiency of the crystal detector and telephone receiver is immediately improved.

There are several simple types of tuning devices. One of these is the inductance coil, which consists of more or less turns of copper wire, suitably mounted. The inductance may be of the fixed type, in which case all the turns must be used as a unit, or of the variable type, in which case any number of turns may be used. Because of the ease with which the inductance may be varied by means of a co-operating device known as the variable condenser, the inductance may be variable in steps of many turns at a time. In this case the variation is obtained by means of a switch, with contact points so arranged as to represent every ten turns of wire. Again, two switches may be used, one switch working by steps of ten or twenty turns,



Simplest receiving set that will give fair results, using a rough tuning coil, crystal detector, fixed condenser and telephone.

while the other switch cuts in one turn at a time. In this manner a relatively fine adjustment may be obtained. If 68 turns represents the proper adjustment, the first switch is turned to the point connecting with 60 turns, and the second switch is turned to the point connecting with 8 turns.

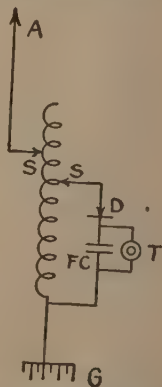


Variable inductance arrangement known as a tuning coil, with double sliders.

A means of fine inductance adjustment is represented in the tuning coil, which has practically passed

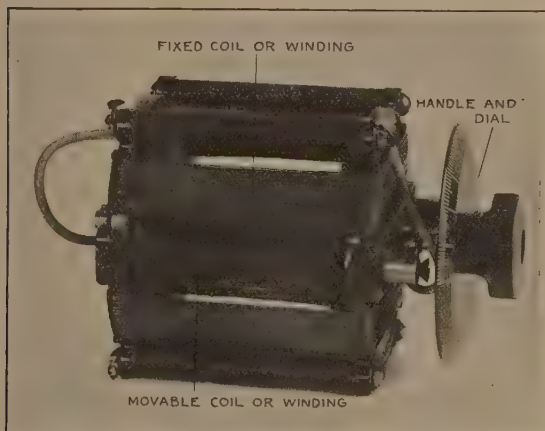
out of use because of its awkward size and adjustment. The tuning coil has a large number of turns of bare or insulated wire wound on a mandrel, with the adjacent turns insulated one from the other. A sliding contact moves over the bared turns, so that contact is established with any turn desired. More than one sliding contact may be used, either on the same slide bar or, usually, on separate slide bars.

There are several ways of connecting the tuning coil, a typical arrangement being indicated in the accompanying diagram. It will be noted that the arrangement here calls for two sliding contacts or "sliders," one being used to vary the wave length of the antenna-ground or wave-intercepting system, and the other to vary the closed circuit containing the detector. It will be noted that this two-circuit arrangement is more efficient than the



Two-slide tuning coil arranged for tuning the antenna-ground circuit and the closed detector circuit.

single-circuit arrangement, and in still more advanced receiving sets the two circuits are even separated from each other, so that there is no electrical connection between the two. A fixed condenser is placed across the telephone receiver, as indicated, to allow the high-frequency energy to pass through the circuit without



The mechanism of the variometer. This form of inductance consists of two sets of coils, one fixed and the other movable, placed one within the other.

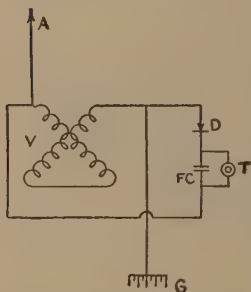
having to force its way through the high resistance offered by the telephone receivers. A crystal detector completes the arrangement.

The tuning coil, with its sliding contacts which do not always make perfect contact, has more or less passed away except in simple crystal receivers used by the beginner. In its place we now find more delicate

devices which give a finer adjustment with a rotary instead of a sliding control. The sharply tuned waves of the radio telephone transmitters make it imperative to use delicate tuning devices in the receiving set, for even a fraction of a turn of inductance makes a considerable difference. So present practice favors the variometer, when it is a matter of variable inductance to be used alone.

The variometer comprises two sets of coils, usually one within the other, the first being a rotatable set known as the rotor, and the other being a stationary

set known as the stator. Both sets of coils are connected in series. As the knob of the variometer is turned, the relationship between these coils is gradually altered. When the variometer dial is set at 180, or whatever may be the maximum dial reading, the coils are so arranged that the current will flow in the same direction through both sets of coils, thus adding inductance or wave length to the circuit. When the dial is set at 0, on the other hand, the two sets of coils



Wiring scheme for a single variometer and crystal detector. This arrangement produces excellent results.

are so arranged that the current will be flowing in opposite directions in both sets of coils, and the coils are now said to be in opposition or "bucking" each other. In that condition the inductance is considerably reduced from the first adjustment, and the wave length is therefore at a minimum.

Hence it will be noted that a considerable range of inductance and resultant wave length values may be

obtained with very fine adjustment by turning the variometer knob. There are no loose contacts to bother with, and the rotary action is far more convenient than the movement of sliders along a tuning coil.

Aside from the variometer, the most popular type of inductance today is in the form of compact coils known as honeycomb coils and duo-lateral coils, according to their characteristic windings. These coils represent fixed inductance, although they

are available in different sizes representing different inductance values. They are obtainable with suitable plug mounts, so that they may be readily plugged in and taken out of a circuit in order to vary the inductance in suitable steps. Compact inductance coils of this kind are also supplied with switches which allow of variation in steps. However, the variation of the wave length when using these fixed inductance coils is brought about by a variable condenser either in parallel—across the winding—or in series with the inductance.



One form of compact inductance coil with a convenient plug mounting.



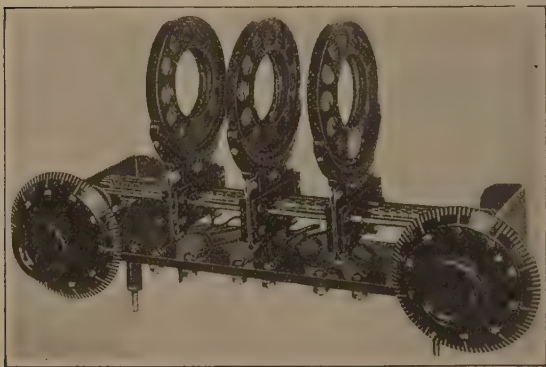
Another form of compact inductance coil with a blade-like form of mounting.

Still another form of compact inductance is

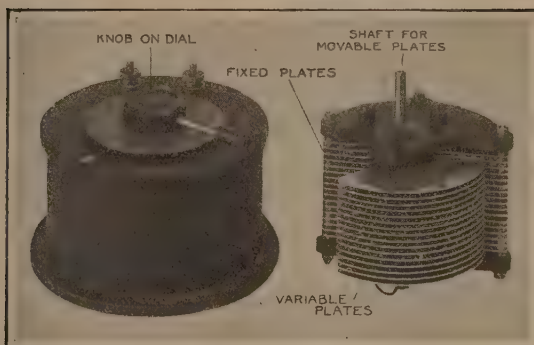
known as the spider-web coil. This is a flat, spiral winding supported by a disk of insulating material which has been cut so as to form radial arms about which the winding is interlaced to hold it firmly in position. There are other types of compact inductances, all of which go to serve the same general end of inductance or, when two are employed, of coupling one circuit with another.

THE VARIABLE CONDENSER AND ITS RÔLE

So far, we have dealt only with inductance as a means of tuning. Inductance makes for greater wave length: the more inductance is placed in a circuit, the greater the wave length. There is another factor for varying wave length, and that is capacity. Capacity



Three compact inductance coils placed in a special support which varies the coupling between them. Note that when the left-hand dial is turned, the left-hand coil moves toward or away from the center coil. The right-hand dial moves the right-hand coil.



Exterior and interior views of a typical variable plate condenser. This form of condenser makes use of a set of fixed plates and a set of movable plates which mesh with the former, thus increasing or decreasing the capacity of the condenser.

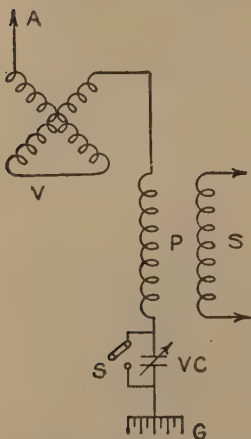
is obtained by means of a condenser, which may be of the fixed or the variable kind. A condenser consists of two conductors separated by a non-conductor or dielectric, and serves to hold opposite charges of electricity. In the fixed type, the size of the conductors or plates, as well as the dielectric, is fixed. In the variable condenser, on the other hand, these factors are variable and make for variable capacity.

The most common type of variable condenser is called the variable plate type, in which two sets of intermeshing plates are employed, one set fixed, and the other set rotatable. As the condenser knob is turned from 0 to the full scale reading, the rotatable plates intermesh more and more with the fixed plates, thus increasing the capacity.

Other less common types of variable condenser make use of mercury, which is squeezed so as to spread it over a larger surface and therefore increase the ca-

capacity effect. There are pressure types, in which the dielectric is squeezed or simply reduced in thickness so as to increase the capacity, as well as other ingenious arrangements.

There is a simple rule that applies to the use of condensers in affecting wave length. When the condenser is in *series* with the inductance, the wave length is *reduced*; and when the condenser is in *parallel* or across the inductance, the wave length is *increased* with the addition of capacity.



How a vario-coupler or loose-coupler is employed. P is the primary, connected in the antenna-ground circuit; S is the secondary. A variometer or a variable condenser tunes the primary circuit

The value of the variable condenser comes in the fine adjustment which it makes possible. Thus the inductance units may be fixed, as already stated, and the variable condenser connected in series or in parallel will give the necessary fine variation, just as the platform scale makes use of large weights for an approximation of the weight, while the beam slider is used for the exact weight. It is for this reason that in many of the present-day receiving sets the inductance is varied in big steps if at all, while the finishing off, so to speak, is left to one or more variable

condensers. In other instances the fine tuning is accomplished by variometers.

The crystal detector is limited to short distances and to weak or moderate audibility in the telephone re-

ceivers. It is out of the question to ask for loud-speaker operation in connection with a crystal detector when used alone. Again, a fairly large antenna must be used in connection with a crystal detector, so that a sufficient amount of radio energy may be intercepted.

Hence sooner or later, and rather sooner than later, the radio enthusiast gets around to the vacuum tube detector, even though it does mean batteries and more elaborate receiving equipment. There is simply no comparison between crystal detector and vacuum tube results as regards volume of sound and distance covered.

THE VACUUM TUBE AND WHAT IT DOES

The vacuum tube is the most interesting as well as the most useful device which has been developed during the progress of the radio art. Without going into the history of this device, it may be said in passing that Edison originally discovered the peculiar behavior of an incandescent lamp filament by inserting an extra wire in a lamp bulb. He discovered the startling fact that when the lamp filament is cold, no current can be passed across the vacuum between the filament and the extra wire or "plate" inserted in the vacuum. However, the moment the filament is brought up to incandescence, a current can be passed across the vacuum gap between the filament and the "plate," but the current can be passed only in one direction, since this device is a uni-directional or uni-lateral conductor. Thus the vacuum tube, as this device is called, may be used to rectify alternating current, since it allows the current to flow in one direction only, and therefore converts alternating current into pulsating direct current. This principle is employed in certain storage battery recharging outfits, as well

as in the detection of radio signals with the two-element or diode tube.

What really takes place in the vacuum tube is subject to a good deal of theorizing, and bulky volumes have been prepared on the subject. It is not within the province of this book to deal with theories, but suffice it to state that the white hot filament gives off millions of infinitesimal and electrically charged particles known as electrons. These electrons travel from the filament to the relatively cold member or "plate" placed in the vacuum tube, the latter being positively charged, and thus form a bridge over which one-way traffic of outside electric current is permitted. Depending on the number of electrons emitted by the heated filament, the bridge is of greater or less capacity, and therefore accommodates more or less current.

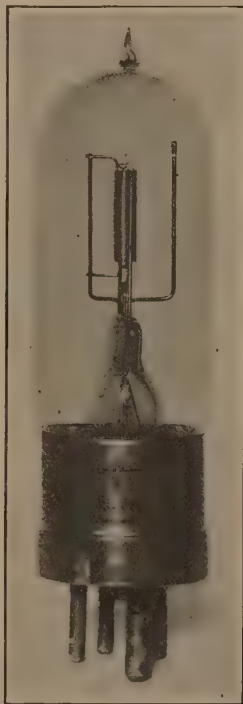
Now in the present-day vacuum tube there is a traffic officer, to use a convenient simile, that decides how much traffic shall pass over the electronic bridge. It was Dr. Lee DeForest, the radio pioneer and inventor, who discovered how the traffic could be regulated and introduced what we are pleased to call a traffic officer. This traffic officer or third member of the vacuum tube, is known as the "grid," because of its gridlike construction, and is placed between the filament and the plate, so that the electrons must pass through the openings in the grid in order to reach the plate. Any electrical charge which is impressed in the grid immediately affects the electronic flow, allowing a greater or less flow; and consequently the external current being passed over the electronic bridge between the filament and the plate, is likewise altered by the grid charge—our traffic officer, as it were.

The vacuum tube is a most sensitive device. The small charge impressed on the grid controls faithfully and instantly a current flowing between the

filament and plate. In this manner it becomes possible to control a strong current by means of a weak current. The incoming radio energy is led to the grid, where it serves to regulate the electronic bridge which in turn controls the electric current traffic passing on to the telephone receivers.

The vacuum tube may be used in a variety of ways, as will be explained later. In the receiving set it is employed as a detector and also as audio-frequency and radio-frequency amplifiers.

When used as a detector, the vacuum tube is arranged so that the incoming radio energy is connected with the grid and one side of the filament. For certain electrical reasons it is necessary to insert a small fixed condenser, known as the grid condenser, and a very high resistance unit known as the grid leak, between the radio-frequency energy and the grid of the tube. Generally the grid-leak and grid condenser are arranged in a single convenient unit. The values of both these devices vary according to



Typical vacuum tube. This particular tube is the WD-11 type, which operates on a single dry cell for the filament current.

the characteristics of the tube employed. At other times the grid condenser is employed as usual, but the grid leak is placed between the grid terminal and one of the filament terminals, although the same purpose is served, this arrangement being necessary because of some peculiarity in the circuit employed.

The slight changes in the electrical charge impressed on the grid by the incoming radio-frequency energy of the radio signals cause the vacuum tube to act as a detector. These slight changes control or affect the plate circuit, because of the changes in the electronic flow, as already described. Since the plate current is quite audible by means of telephone receivers, any changes in this current brought about through the influence of the grid, are immediately detected in the telephone receivers, hence we have the reproduction of the original sounds of the broadcasting studio.

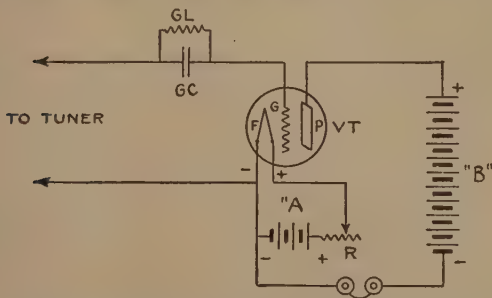
THE A-, B-, AND C-BATTERIES

Now the use of any vacuum tube involves a battery for heating the filament, which is known as the filament or "A" battery. Some types of vacuum tubes call for a storage battery to operate the filaments, while others, requiring little current, call for dry cells. The tendency today seems to be more and more in favor of the dry-battery vacuum tubes, because of the low first cost, convenience, portability, and cleanliness of the dry battery. However, the fact remains that tubes operating on a storage battery produce more powerful results, hence the preference for such tubes with their troublesome battery by numerous radio enthusiasts.

The filament current, ranging in potential from $1\frac{1}{8}$ volt for certain dry battery tubes to 6 volts for the storage battery tubes, is controlled by a variable resistance, known as the rheostat. This consists of a winding of resistance wire, more or less of which is

inserted into the circuit by means of a sliding contact. To ensure precise adjustment of filament voltage, which is necessary in the critical tubes sometimes used as detectors, use is made of a vernier rheostat, in which a very fine adjustment, even to the fraction of a turn of wire, is obtainable.

For the critical adjustment of the filament voltage there are several different types of compression resistances. These types make use of a pile of carbon



General idea of the vacuum tube detector's arrangement in a circuit: GL—grid leak; GC—grid condenser; F—filament; G—grid; P—plate; VT—vacuum tube; "A"—filament battery; R—rheostat for filament variation; "B"—plate battery or so-called B-battery; and telephones.

disks which are more or less squeezed together, so as to vary the current flowing through them. The applied voltage may be delicately varied by such means, although with some makes of compression resistances there is some danger of extraneous noises due to improper contact between the successive disks.

Aside from the filament or "A" battery, there is the "B" or "plate" battery. In the early days of vacuum tubes, a number of flash-lamp batteries were connected

together so as to obtain the necessary high voltage for the "B" battery. Today, however, there are special dry battery units in convenient sizes and shapes to supply $22\frac{1}{2}$ or 45 volts and even higher potentials. The dry "B" batteries come in two types, namely, the fixed voltage and the variable voltage types. The former has just two terminals, from which the full potential of the battery is obtained. The latter has a number of terminals, permitting of a number of different potentials to suit the requirements of the vacuum tube. The so-called "soft" tubes, which are still used to some extent as detector tubes, operate best on 15 to 20 volts, accurately determined, hence a variable "B" battery should be employed. The so-called "hard" tubes, which are now in almost universal use, operate on 45-volts, hence the fixed voltage "B" battery may be employed.

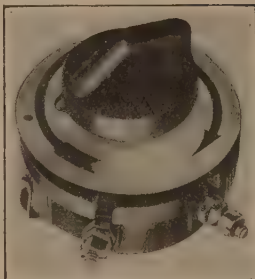
There are now available special, low-capacity, high-voltage storage batteries which may be used in place of the dry-battery units when a set is apt to be subjected to extensive use. Such storage batteries may be readily recharged and their operating cost must of necessity be lower than when using dry batteries which, when discharged, are worthless and must be thrown away.

The time is not far distant when we shall probably operate our vacuum tubes on lighting current. The problem here involved is a rather intricate one, but there are signs that ultimately we shall operate our vacuum tubes from the usual socket, thus dispensing with "A" and "B" batteries except in portable sets and the simpler receivers. A step in that direction is the vacuum tube power unit now put out by a leading storage battery manufacturer. This unit contains storage battery cells which are connected with a chemical rectifier and recharger. The storage batteries can "float" across the lighting current line, being con-

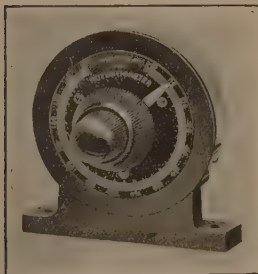
stantly on charge if desired, while the vacuum tube requirements are met at the same time.

There has lately appeared an ingenious device known as the "thermoformer," based on the thermo-electric principle, which serves to convert standard A. C. or D. C. current into suitable filament and plate current supplies for vacuum tubes. In the thermo-

former full use has been made of the thermo-couple idea, which consists of two dissimilar metals in contact, one being heated and the other remaining cold. Electricity is generated by such an arrangement. The usual electric light current, tapped at the nearest electric light socket, serves to heat the thermo-couples. Demonstrations prove



Typical rheostat, consisting of a resistance winding on which slides a contact arm, a panel plate and a knob.

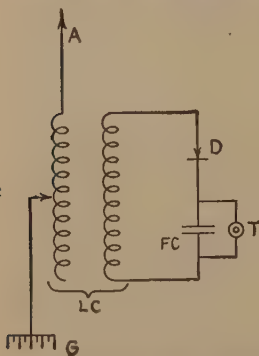


Typical potentiometer for very fine adjustments of applied electrical energy.

that the thermoformer harnesses the usual electric light current to the usual vacuum tubes without the slightest hum or other indication of the use of A.C. or D.C. current supply in place of the conventional dry cells or storage battery. Furthermore, the thermoformer shows a marked economy in operating cost over the usual batteries.

PRIMARY AND SECONDARY CIRCUITS AND HOW THEY ARE COUPLED

So far, the circuits have been of the simplest types, with a physical connection between the antenna-ground or wave-intercepting system, and the closed circuit in which the detector is placed, known as the detector circuit. Now for reasons which need not be explained here, since this work does not attempt to concern itself with the theories or the mathematics of radio but rather with the application of the results, many sets



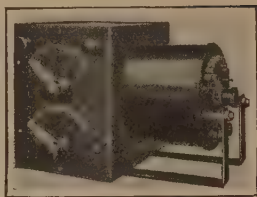
How a coupling effect is used with a crystal detector. In this instance the primary is adjustable, while the secondary is fixed. A—antenna; G—Ground; LC—loose-coupler; FC—fixed condenser; T—telephone; D—detector.

make use of distinct antenna-ground and detector circuits, with no physical connection between them. Transference of energy from the former to the latter is effected by means of two windings, which are brought into more or less close inductive relation. In one form of coupling we have a movable coil sliding within a fixed outer coil, the device being known as a loose-coupler. In another form two sets of coils are employed, one turning within the other in a manner quite similar to the variometer. this form being known as the vario-coupler. Still another form calls for the use

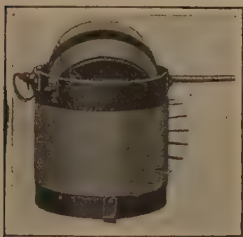
of compact inductance coils as already described, mounted on hinged holders so that they may be swung toward or away from one another.

In keeping with modern practice which has done away with sliding arrangements in favor of rotary adjustments, the vario-coupler has become the standard device for coupling the wave-intercepting and the detector circuits.

So far, we have the following elements with which to tune and arrange our radio circuits: inductance, represented by inductance coils or variometers; capacity, represented by fixed and variable condensers; and the coupling, represented by coupling coils and the vario-coupler, as well as the loose-coupler arrangement which is passing out of use. No matter how elaborate the receiving set may be, these fundamental factors—inductance, capacity and coupling—are the foundation upon which the radio engineer builds. With these fundamentals



Loose-coupler employed for coupling one circuit with another. This type of coupling is being replaced by the vario-coupler.



Typical vario-coupler, with a rotatable secondary and a fixed primary provided with taps for varying the inductance value.

the radio engineer makes up all types of receiving sets, ranging from the simplest crystal detector type to the five-tube receivers. However, the layman is led into believing that there is a radically new set being developed at the rate of one every week. This is due to the giving of new waves to old circuits. Frankly, there is little that is new in these weekly sets except their names.

THE QUESTION OF TELEPHONE RECEIVERS

Little or nothing has so far been said regarding the telephone receivers, yet here is an important member of any receiving set. In fact, no matter how elaborate a receiving set may be, if the receivers are not of the best available type the results are not what they might be.

Radio telephone receivers are not just ordinary telephone instruments. They are far more sensitive than anything that is ever used in regular line telephony. First of all, they are constructed with the utmost care; secondly, they have windings of very fine wire, as compared with the relatively large wire used in the ordinary telephone receiver. Thirdly, the diaphragm of the usual radio receiver is far thinner and therefore more delicate and more responsive to the slight magnetic variations due to the passage of weak currents through the telephone windings, than the usual telephone receiver's diaphragm. Fourthly, in certain types of radio receivers the two receivers of the head set are matched in tone, so that both ears receive precisely the same sounds. This feature makes for the utmost response in the human ears and therefore the best results.

Now with a single vacuum tube used as the detector in a radio circuit, a pair of telephone receivers may be operated with good results. In fact, two pair of receivers may be operated if desired, for there is sufficient energy available for the purpose. However, if louder signals are desired, it becomes necessary to make use of amplification, or the building up of the sound volume. This is known as audio-frequency amplification.

Something has already been said regarding the action of the vacuum tube. We have learned of the flow of electrons from the hot filament, and how this flow of

electrons forms a one-way bridge for the "B" battery or plate energy connected with the telephones. And the grid, as we have learned, is the control for the traffic over this one-way bridge. In the case of the amplifier tube the grid is again employed as the control. Instead of using a pair of telephone receivers in the plate circuit of the receiving set, the two leads or "output" from the detector circuit are brought to the amplifier arrangement. In this event the output of the detector is passed through the primary winding of the amplifying transformer. Audio-frequency transformers are available in different ratios for the primary



Plug used for introducing a pair of head-phones or a loud-speaker into a circuit provided with the companion device known as a jack. The plug is also used for other purposes, especially in laboratory work and in transmitting.

and secondary windings, for the purpose of bringing about greater or less amplification. However, owing to certain distortion possibilities, it is sometimes advisable to use the lower ratios as will be explained further on, in the chapter dealing with amplification.

The secondary winding of the transformer is connected with the grid of the amplifier tube and the filament of the same tube. The plate circuit of the amplifier tube contains a "B" or plate battery of 45 volts or more, this high voltage being supplied to the telephone receivers or a small loud-speaker. Now, if additional amplification is desired, another amplifier

or "stage" of amplification is added. In such event the output of the first stage of amplification is delivered to the transformer primary of the next stage, while the secondary of that transformer is connected with the grid and the filament of the second amplifier tube, the output of which is brought to the telephone receivers or loud-speaker, as the case may be. A third stage of amplification may be added in the same manner, and three stages of audio-frequency amplification are considered as the practical limit. Most receiving sets make use of but two stages. It should be noted that the same filament battery and the same plate or "B" battery are used for the detector and the amplifying tubes.

AUDIO OR RADIO FREQUENCY—WHICH?

The amplifying arrangements described so far, it will be noted, are of the audio-frequency type. As already explained earlier in this work, audio-frequency amplification increases the volume of sound obtained with a given receiver, but it does not increase the sensitiveness or the "reach" of that receiver. The reason for this is that the usual vacuum tube detector is very much like a gun in its operation. A certain amount of radio energy must be applied to the grid before the tube will function. The grid is, after a fashion, an electrical trigger. No matter how many stages of audio-frequency amplification may be piled on after the detector, if the initial radio energy is insufficient to "trigger" the detector, the signals will not be heard.

Hence we must resort to another form of amplification which will build up the radio energy before passing it on to the detector. This form of amplification is known as radio-frequency amplification, which is

coming more and more into use, especially in long-distance reception and in connection with loop receivers and receivers using small indoor antennæ.

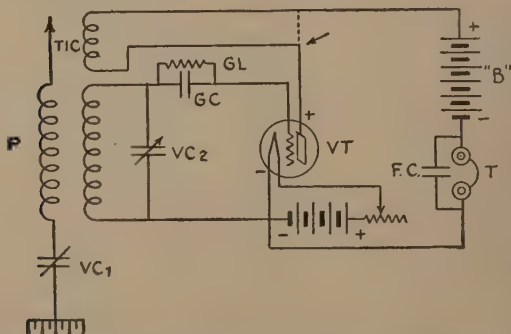
Aside from the remarkable sensitiveness secured through the use of radio-frequency amplification, the advantage of this amplification lies in the fact that it amplifies only the radio energy and not the many little irregularities and imperfections which exist in the usual receiver and audio-frequency amplifiers. Thus several steps of radio-frequency may be added to the receiving set without distorting the signals or introducing extraneous noises, while audio-frequency amplification is quite limited to two or three stages.

So far, then, we have the following elements for our receiving set: Inductance, capacity, and coupling, for the tuning arrangements; the crystal detector for simple receiving sets and the vacuum tube for the more elaborate forms; the telephone receivers and loud-speakers for converting the intercepted radio energy into sound values; audio-frequency amplification for building up the sound values to the desired degree; and radio-frequency amplification for building up the radio energy so as to make the receiving set more sensitive and far reaching with a given wave-intercepting system.

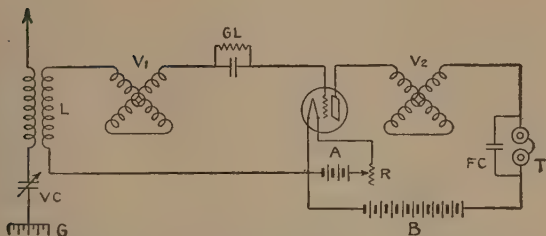
REGENERATIVE RECEPTION OR SELF AMPLIFICATION

Thus far, the various receiving arrangements described have employed the detector purely as a detector and nothing else. The radio-frequency energy has been brought right to the detector, in the simpler sets, or passed through a radio-frequency amplifier and then to the detector. The detector, in turn, has delivered its output to an audio-frequency amplifier or directly to the telephone receivers. Now, if instead of turning

the detector output loose, so to speak, we take part of that output and lead it back or re-impress it on the grid of that detector tube, it will add materially to the voltage of the incoming signal. This will naturally give a greater charge on the grid, and consequently result in a greater variation of plate current, which in turn makes for greater output or greater sound volume. It also makes for a more sensitive tube, since the radio-frequency energy is being amplified in this manner. The single tube is now operating as a detector and amplifier combined. This practice is known as the regenerative or feed-back arrangement, and constitutes one of the greatest advances made in radio engineering. Edwin H. Armstrong, already referred to in our first chapter, is generally credited as the originator of this remarkable arrangement for the



Regenerative circuit employing a tickler coll. P—primary of vario-coupler; TIC—tickler coll; VC-1—variable condenser for antenna-ground circuit; VC-2—variable condenser for secondary circuit; GL—grid leak; GC—grid condenser; VT—vacuum tube detector; B—plate or B-battery; FC—fixed condenser; T—telephones. Dotted line indicates wiring for non-regenerative circuit.



Another method of obtaining regeneration. L—vario-coupler; VC—variable condenser in antenna-ground circuit; V-1—variometer in grid circuit; GL—grid leak and condenser; A—filament battery; R—filament rheostat; B—plate or B-battery; FC—fixed condenser; T—telephones; V-2—plate or “feed-back” variometer; G—ground.

usual vacuum tube detector, although recent court decisions tend to give credit to Dr. Lee De Forest.

There are two methods in general use for obtaining the regenerative effect. The first makes use of what is known as the tickler—an extra coil which is brought near the inductance or winding connected with the grid of the detector tube. Thus the simplest type of regenerative receiver consists of three compact inductance coils, adjustably mounted, two being connected with the antenna-ground system and the detector circuit, respectively, and the remaining one with the plate circuit. The third coil is mounted so that it can be moved nearer, or farther away from the secondary coil so as to impress or “feed back” more or less of the plate energy back to the grid of the detector tube. The adjustment between the tickler coil and the secondary coil is of great importance, for the regenerative or feed-back action must be delicately regulated to ensure the maximum results.

The second method of obtaining the regenerative effect makes use of a tuning arrangement in the plate circuit, which tunes that circuit until it feeds back

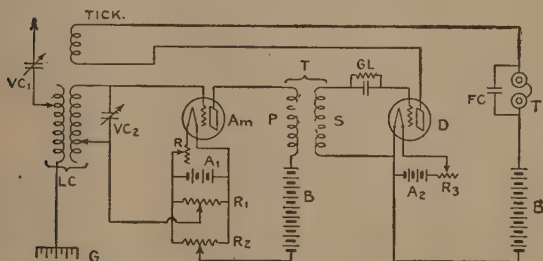
energy to the grid of the tube. The most common method is to use a variometer in the plate circuit.

All regenerative sets are delicate to operate, for the regenerative effect must be controlled so as to obtain the maximum signal strength without distortion. If the regeneration is pushed too far, the tube begins to oscillate, which means that it begins to generate high-frequency waves that not only set up troublesome interference with incoming signals and cause no end of distortion and strange noises, but it also sends out a wave through the antenna-ground system which interferes with the reception of others within a radius of a quarter-mile and sometimes more. Indeed, in the first chapter this matter of regenerative receiver interference was dealt with at some length. Still, it must be admitted that the regenerative arrangement makes for remarkable sensitiveness and sound volume with the simplest kind of receiver. In the hands of capable operators, it should cause no interference whatsoever. It remains today, despite the many improvements made in radio-frequency amplifiers, the simplest yet most effective method of radio-frequency amplification.

As for radio-frequency amplification, then, we have the regenerative arrangement, which is radio-frequency amplification but is generally not included in that category; and of radio-frequency proper, we have two kinds, namely, the tuned radio-frequency amplification, and the untuned. In the tuned radio-frequency amplification we have a circuit comprising inductance and capacity, one or both factors being adjusted so as to tune one circuit to another circuit and therefore obtain the maximum transference of energy from one to the other. Here again, as with audio-frequency amplification, the first tube receives the weak energy from the wave-intercepting system, builds it up, passes it on to the next stage of amplification, and so on. The plate

energy from one tube is transferred to the grid of the next tube.

In the untuned or transformer-coupled radio frequency, use is made of fixed-winding transformers in much the same manner as in audio-frequency amplification. Of the tuned and untuned arrangements, the former is far more efficient; indeed, two stages of untuned radio frequency are usually not as efficient as a single stage of tuned. However, tuned radio frequency



Typical radio-frequency amplifier arrangement, in which one stage of radio-frequency amplification precedes the detector, and regeneration is employed. VC-1—variable condenser in antenna-ground circuit; LC—vario-coupler; VC-2—variable condenser in secondary circuit; Am—amplifier tube; R—filament rheostat; R-1 and R-2—potentiometers; R-3—filament rheostat; P and S—primary and secondary of radio-frequency transformer; GL—grid leak and condenser; D—detector; B—plate or B-battery; A 1 and A 2—filament batteries; FC—fixed condenser; T—telephones; TICK—tickler coil; G—ground.

calls for a multiplicity of controls and is therefore not as desirable, at times, as the untuned kind with a minimum of controls.

The more advanced receiving sets of today call for one or two stages of radio-frequency amplification, a detector and one or two stages of audio-frequency amplification. When radio frequency amplification is not employed, the regenerative feature is incorporated since

a detector without radio-frequency amplification of some kind is not sufficiently sensitive for satisfactory operation. Some circuits combine tuned radio-frequency amplification and regeneration. Whereas the radio receivers of the early days of broadcasting generally called for a single tube—the detector tube with the regenerative feature—the present-day sets often call for five and six tubes. Some arrangements even call for eight tubes and over.

With a view to reducing the number of tubes required and thus reduce the size of the filament and plate batteries, and therefore the operating expense, a method has been worked out whereby the tubes employed for radio-frequency amplification can be used for audio-frequency amplification as well. In such an arrangement the tubes serve first as radio-frequency amplifiers, their output is passed on to the detector, and the audio-frequency output of the detector is fed back to the radio-frequency tubes which now serve as audio-frequency amplifiers. This is known as reflexing, and makes for a relatively simple set of maximum efficiency. To simplify matters it is generally found advisable to employ a crystal detector, with its silent operation, in preference to a vacuum tube detector. Inasmuch as there is ample radio-frequency energy available, the crystal detector works well and its silent operation, without distortion, is very desirable.

And so we have the following factors now available for our receiving sets: the wave-intercepting system, which may be an antenna-ground arrangement, loop, or small indoor antenna used with or without a ground according to the circuit employed; the tuning system, made up of inductance, capacity, and coupling; the detector, represented by the vacuum tube and crystal types; the audio-frequency amplifier; the telephone receivers or loud-speakers; the radio-frequency amplifier for building up the radio energy before passing it

on to the detector; the regenerative device whereby the tube is made to serve as a detector as well as an amplifier; and finally the reflexing arrangement which permits of double duty from a given set of tubes. These are the factors employed in all standard radio receiving sets. These factors may be arranged in an almost endless variety of ways, but the fundamentals remain the same.

AND THE LAST WORD—THE SUPER-HETERODYNE

In order to obtain the simplicity of the fixed radio-frequency amplifier with the maximum of efficiency, there has been worked out what is known as the super-heterodyne circuit, developed by the same Edwin H. Armstrong to whom we owe credit for the regenerative receiver. In the super-heterodyne receiver, which is explained more or less at length in one of the last chapters in this work, the incoming radio wave is passed through the first detector and then played off against a locally-generated wave or frequency for the purpose of obtaining the well-known "beat" phenomenon, in this case the "beat" being a long-wave or low-frequency energy which can be passed through what is known as an intermediate-frequency amplifier. When one frequency is played off against another, there is a "beat" resultant or third frequency which represents the difference between the two original frequencies. Thus an incoming wave of 610 kilocycles, or 610,000-cycle frequency, when played off against a locally-generated wave of 600 kilocycles, or 600,000-cycle frequency, produces a new wave or "beat" effect of 10,000-cycle frequency, which is the difference between the two original frequencies.

The locally-generated frequency is produced by a vacuum tube in an oscillating circuit with inductance and adjustable capacity in the form of a variable condenser. In the super-heterodyne circuit the incoming

wave is tuned by means of one condenser, while the local generator or oscillator is tuned to the desired interfering wave length. When the proper resultant frequency or "beat" frequency is obtained, it is passed through several stages of so-called intermediate-frequency amplification, which is higher than the audible-frequency range and lower than the radio-frequency, and has the desired advantage of operating at marked efficiency over quite a wavelength or frequency range. Hence it can make use of fixed transformers without impairment of efficiency. The amplified energy is now passed to a second detector, which in turn delivers its output to the audio-frequency amplifier. Thus the super-heterodyne has the several advantages of remarkable sensitiveness with a small loop wave-interceptor; it filters out undesired stations with remarkable precision; it has but two simple controls, despite its multiplicity of tubes; and it gives loud, clear loud-speaker reproduction.

THE BASIC RECEIVER CIRCUITS

We have just a few basic circuits on which all receivers are based, despite the many names given to the present-day offerings. In fact, nothing serves to confuse the layman so much as the weekly appearance of some new circuit with some high-sounding name. With but very few exceptions, these new circuits are little more than new names given to old circuits in slightly camouflaged or revamped form.

Our basic circuits, then, are as follows:

- 1.—The *simple crystal receiver*, with the most elementary kind of tuning device.
- 2.—The *simple vacuum tube receiver*, with the most elementary kind of tuning device and no provision for regeneration.
- 3.—The *regenerative receiver*, in which the plate out-

put of the vacuum tube detector is returned to the grid in order to increase the potential of incoming signals, and thus produce self-amplification.

4.—*Audio-frequency amplification*, which is used in connection with all kinds of receivers in order to increase the audio-frequency output so that it will operate telephone receivers with sufficient volume or operate loud-speakers.

5.—*Tuned radio-frequency amplification*, in which each stage is tuned so as to secure the transfer of radio energy from one stage to the next.

6.—*Untuned radio frequency amplification*, making use of transformers which require no adjustments.

7.—The *reflexing* arrangement, whereby a set of tubes is made to do double duty, first as radio-frequency amplifiers and then as audio-frequency amplifiers.

8.—The *super-heterodyne* system, whereby the incoming radio wave is played off against a locally generated wave, so that the difference between the two, or so-called "beat" effect, is of suitable frequency to be handled efficiently by fixed intermediate frequency amplifiers, and passed on to a second detector for conversion into audio-frequency current.

It should be noted that the foregoing basic circuits are often grouped together into a single receiver. Thus we find regeneration combined with audio-frequency amplification; radio and audio frequency combined into a single receiver; radio and audio-frequency worked out by means of the reflex arrangement into a single receiver; regeneration combined with radio-frequency amplification, followed by audio-frequency amplification; the super-heterodyne arrangement combined with reflexing and audio-frequency amplification, and so on. But if any present-day receiving set is carefully analyzed, it is soon reduced to its basic components.

In the next chapter, in which we deal with some of the more common types of receiving sets now on the market and those which may be constructed by the handyman, it is interesting to note how these basic circuits are used over and over again under a variety of names.

CHAPTER IV.

BUILDING OR BUYING THE RECEIVING SET TO FIT ONE'S NEEDS

RADIO receiving sets, like clothes, may be made to order or ready made, according to one's preference. In either event the main point is that the radio set fit the requirements, just as a suit is of little value if it is two sizes too large or too small.

The first consideration regarding a prospective radio receiving set is the eternal question of dollars and cents. Whatever latitude there may be in types and finishes of radio equipment, the great criterion is the pocketbook of the buyer. It goes without saying that the greater the pocketbook available for radio, the simpler becomes the task of choosing the proper receiving set.

TO BUILD OR TO BUY—THAT IS THE QUESTION

The first question that confronts the prospective owner of a radio set is whether to build or buy. At first glance this would appear to be merely a matter

of saving money by doing the work one's self, whereas, strange as it may seem, the time has now come, thanks to quantity production on the part of some of the largest radio manufacturers, when the simpler receiving sets can be purchased complete for less than it would cost to build them from the separate parts. On the other hand, certain well-known circuits can be built just as well as the manufactured sets, and at two-thirds the cost or less.

The main objection to building one's own set is that in the long run this often proves an expensive procedure. There are tens of thousands of radio enthusiasts who started out with a home-made set to which they have been constantly adding something new, until today they have a conglomeration of parts representing a far greater investment than if they had invested in a good set in the first place. That, in truth, is the danger of building one's own set. It is so easy to start out with a simple circuit and keep adding something here and something there, until finally one is appalled at the investment with so little to show for it. It is very much the old story of the cheap automobile, which is constantly improved with various accessories and special finishes until the completed job represents as much as a real good make of car.

The author goes on record at this point to state that it does not pay to build a simple regenerative set. Of course there will be protests from dealers and manufacturers of parts which are being sold under new and attractive names. The market is flooded with all kinds of circuits of different names—names, please note, rather than basically new circuits. The old and reliable regenerative circuit, especially the single-circuit variety, is being sold to the unwary radio buyer under all kinds of attractive names, for which fantastic claims are made.

Yet the truth of the case is that one can buy a

complete regenerative receiver of reliable make and good finish for less than the cost of the parts. At least two large manufacturers are now marketing excellent regenerative sets which more than compete



Simple regenerative receiver with one stage of audio-frequency amplification. Sets of this general type are now available at moderate prices well within the reach of every one. In fact, it no longer pays to build a simple home-made receiving set.

with the crude, home-made products assembled from parts.

When it comes to some special piece of apparatus such as an amplifier, there may be an excuse for build-

ing one's own. It is true that some radio parts are better than others, and a manufacturer does not always use the best. Thus in the case of an audio-frequency amplifier the fastidious radio enthusiast may desire to use one of the best makes of transformers, in which event it is worth his while to buy those transformers and assemble his own unit or set.

Advancing to the more elaborate receivers, there begins to be a real object in constructing one's own instrument. The prices asked for the more elaborate receivers are such as to represent quite a margin over the cost of the parts and materials. Thus some of the receivers selling for \$150.00 may be constructed from parts and materials costing \$60.00, so that the radio enthusiast saves \$90.00 by supplying his own labor. Or again, if the radio enthusiast does not wish to do the work himself, there is often an appreciable saving in buying the parts and materials and having a skilled radio man assemble the set.

In the case of the most advanced receiving sets there is a decided advantage in building one's own apparatus, for these types of sets are still in the experimental stage, and a home-made set can incorporate the very latest ideas on the subject, while making use of the finest available parts. Furthermore, the set can be put together in such a manner as to leave room for the improvements that are bound to come along.

There is nothing complicated about building a radio set. The work is simply a matter of assembling neat parts and connecting them with wire or bus bars. The only skill involved is in the matter of drilling the panel accurately, as well as the handling of the soldering iron with which to solder the joints. Even so, panels may now be obtained completely bored and finished, ready for the mounting of the instruments. And as for the soldering, there are certain connecting devices

available which do away with the soldered joint. There is no reason why the home-made set cannot be made quite as neat as the manufactured product, es-



Amplifier unit for the receiving set shown on page 129. This amplifier is of the push-pull type, making for the best possible results with a small loud-speaker.

pecially if such finishing touches as having the panel engraved or suitably labelled, are carried out.

The last part of this work is devoted to the con-

struction of sets. In it will be found data on the construction of simple as well as elaborate present-day receivers. Before embarking on the construction of a set, however, the reader must be sure to ask himself whether, in the long run, it will pay him to build his own. If he will be satisfied with what he builds, no matter how much it may ultimately cost, all well and good. But it is well to remember that the simple home-made receiver often mounts by leaps and bounds until it costs more than would a high-grade manufactured set.

WHAT KIND OF TUBES—DRY-BATTERY OR STORAGE BATTERY?

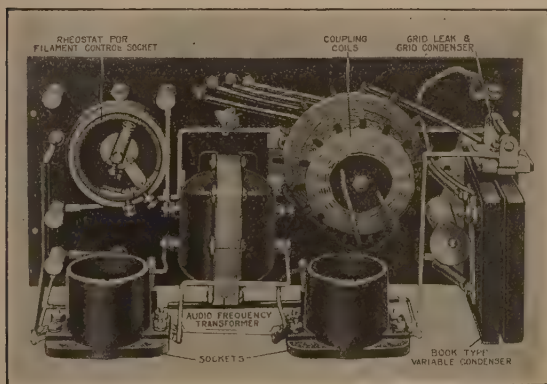
The first question to be settled in deciding on the type of home-made or bought radio set is the kind of vacuum tubes to be used. Today there are excellent tubes for use with dry-battery, as well as economical tubes for use with the good old storage-battery.

Thanks to the development of special filament materials, such as the oxide-coated filament and the thoriated filament, dry-battery tubes are remarkably efficient, especially in view of their low current consumption. The oxide-coated filament tubes, such as the WD-11 and WD-12 and corresponding tubes of other makes, draw one-quarter to one-fifth of an ampere, and usually operate on a potential of $1\frac{1}{2}$ volts and less, which means that a single tube of this kind can be run off a single dry cell.

Still more remarkable are the thoriated filament tubes, which require as little as .06 ampere—six hundredths of an ampere, or about one-eighteenth of an ampere. This exceptionally low current consumption makes it possible to operate three or four of these little tubes on three dry cells connected in series. A potential of $3\frac{1}{2}$ to $4\frac{1}{2}$ volts is required. A single,

dry-battery, thoriated-filament tube, such as the UV-199 and corresponding types, will operate on three small cells of flashlight battery. These diminutive tubes have made compact portable sets possible.

It would seem very much as though everything is in favor of the dry-cell vacuum tube, with its low-current consumption, high efficiency, compactness be-



Behind the panel of a typical inexpensive receiving set of the regenerative type with one stage of audio-frequency amplification. Note the odd book-type variable condenser, which opens up or closes like a book to vary the capacity. Also note the simple coupling coils, one fixed and the other movable, for the regenerative effect.

cause of the dry battery, cleanliness for the same reason, and so on. Instead of investing \$12 to \$25 for a storage battery, one need not spend more than \$2.00 or less for a few dry cells. However, there is another side to the story. The storage-battery tubes, such as the UV-201-A and C-301-A, are considerably more powerful

than the dry-battery tubes. Consequently, better results are obtained in the way of volume, especially in loud-speaker reception; and many radio enthusiasts still find it preferable to use the messy storage battery and trouble themselves with recharging in order to have the volume of sound obtainable only with a storage-battery outfit.

So, finally, the question is simply one of getting good results with the clean, compact, inexpensive dry battery, or getting the very best results known with the heavy, somewhat troublesome and expensive storage battery. With a plurality of tubes, as in the case of some of our more elaborate present-day sets, sufficient volume is obtained with dry-battery tubes.

Some of the very finest receiving sets now being offered to the public are dry-battery sets. It does seem to indicate that the dry-battery tube is in the ascendancy.

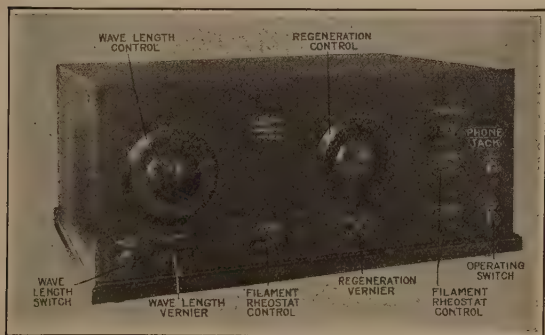
HOW MANY TUBES?

Again, in deciding on a receiving set, whether it is to be home-made or manufactured, the next consideration is how elaborate it should be. And this is but another way of asking how many tubes should it include. Tubes determine the power of the receiving set, more or less; and power determines what the set will do.

Thus if the radio enthusiast is satisfied with telephone receiver reception, then a single-tube set will do. In order to make that set really sensitive and capable of good sound volume with telephone receivers, it should be of the regenerative type. Thus we have the single-circuit single-tube regenerative set, which is as simple as it is efficient. It may be used to receive from broadcasting stations within a radius of several hundred miles under average conditions, and

will receive up to 1,500 miles under exceptional conditions, using a fair-sized antenna;

Now if the volume of sound obtained with the head set is considered insufficient, and louder music is desired, a single stage of audio-frequency may be added. Thus we have simple regenerative receiving sets which include a detector and one stage of audio-frequency, or two vacuum tubes in all. Still further, if it is desirable to have a loud-speaker instead of the head set,



One of the better kind of regenerative receivers, with two main tuning controls and auxillary tuning controls known as verniers, for finer adjustments. This set operates on dry cells, which are placed at the rear of the cabinet.

and sooner or later practically every radio enthusiast turns to the loud-speaker which is ever so much more desirable than ear-phones, it is necessary to use a two-stage audio-frequency amplifier, which may either be built right in the receiving set cabinet, or added as an extra unit.

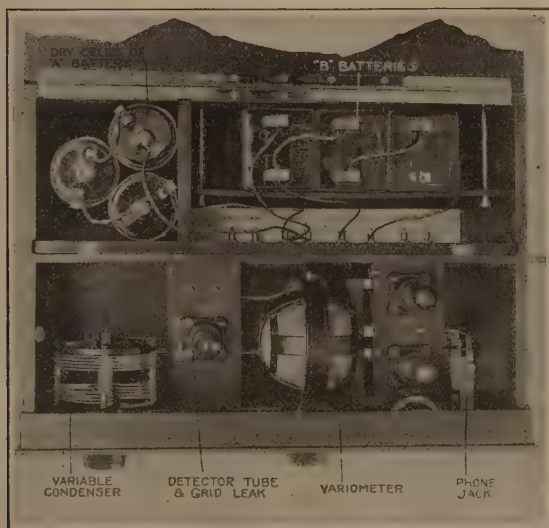
Of late there has been a marked tendency to dis-

credit the regenerative type of receiving set. Yet, as a matter of cold truth, it is a remarkable circuit. In the hands of the intelligent operator, it gives marvelous results; indeed, a properly made regenerative receiver will often give as good results as an elaborate set making use of two stages of radio-frequency amplification. It is no doubt true that the regenerative receiver, especially certain home-made types of crude design, may be made to oscillate and emit a troublesome wave which will interfere with other receivers in the immediate vicinity, and thus become a nuisance in the hands of ignorant or careless operators; but the same thing may be said of any automobile in the hands of the irresponsible joy-rider. Surely, it is no reflection against the machine itself.

Manufacturers of regenerative receivers have not been slow to realize the need of preventing troublesome interference. The worst offender in this respect has been the simple, single-circuit regenerative set, which, truth to tell, gives excellent results in connection with a two-stage amplifier and loud-speaker. The tendency now is to avoid the single-circuit design as much as possible, or, if it is used, to modify it in such a manner as to reduce to a minimum the interference possibilities. One manufacturer has even developed a special unit in the form of a single-stage radio-frequency amplifier, known as a "clarifier," which is placed between the regenerative set and the wave-intercepting system, and serves not only to prevent interference or re-radiation, as it is called, but increases the sensitiveness and volume obtained with the set. Other devices with the same object in mind are being introduced. However, the main objection to some of these is that they cut down the efficiency of the receiver in the course of preventing interference to others.

COMBINED RADIO FREQUENCY AND REGENERATION

The regenerative idea is really too good to be abandoned, and it is well that some manufacturers realize that fact. Thus we have receivers making use



Looking down into the cabinet of the receiving set shown on page 135, showing the variable condenser and variometer units, the tubes, and the filament dry cells and "B" batteries in their compartments at the rear of the cabinet.

of tuned radio-frequency amplification together with regeneration. From the three-tube regenerative set—the detector and two stages of audio-frequency amplification—already covered, we go on to the four-tube

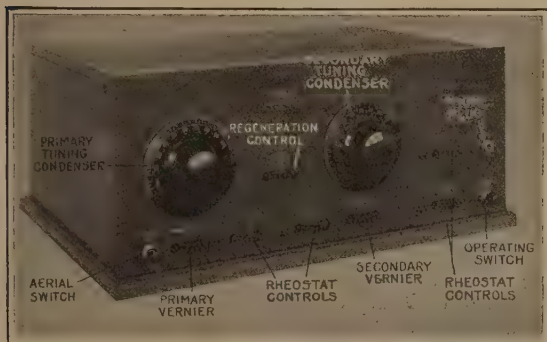
set making use of one stage of radio-frequency amplification, the detector with regeneration, and two stages of audio-frequency amplification. The combined radio-frequency and regenerative receiver is remarkably sensitive and produces excellent results. It requires but a very small antenna; one well-known make of this type is provided with a twenty-foot length of silk-covered wire which is laid on the floor or placed behind the picture-frame moulding of a room, for the wave-intercepting system. It may be that the combined radio-frequency and regenerative receiver is a little difficult to tune, but the results are quite worth while.

From the plain combination of radio-frequency and regeneration, we pass on to the very latest sets in which the regeneration is handled in a novel manner in combination with radio-frequency. Various names have been given to these combinations, but the fact remains that they are simply a combination of radio-frequency with that remarkable thing known as regeneration.

THE RADIO FREQUENCY FAMILY OF RECEIVERS

Just so long as plain tungsten-filament vacuum tubes were used, requiring a trifle over one ampere of current for each one, the three-tube set was about the limit of practical amateur reception. Thus the most popular receiver was the regenerative type, in which the detector tube was made to do double duty as a detector and as an amplifier. But with the advent of the new thoriated filament tubes as well as the oxide-coated filament tubes, with a current consumption of .06 ampere to .25 ampere, there is no longer any objection to using five tubes or more, whether operating on a storage battery or dry battery for the filament energy.

So the radio-frequency amplification, which requires additional tubes, has come into general use. At the time the first edition of this work was being written, radio amplification was talked of by radio men with abated breath. Wild stories were circulated of the elusiveness of radio-frequency currents and how hard they were to tame. Yet today we handle radio-fre-



Four-tube set which combines radio-frequency amplification with regeneration. Excellent results are obtained with such an arrangement, although the tuning is more critical and therefore more difficult than in some of the other present-day receivers.

quency with the greatest abandon, having reduced it to a cut-and-dried, foolproof thing which is available in many of the present radio offerings.

There are many types of radio-frequency receivers now on the market. The usual arrangement is to have two stages of radio-frequency amplification following the tuning arrangements, backed up by the detector and two stages of audio-frequency amplification. The radio-frequency amplification may be in the form of fixed radio-frequency transformers or tuned

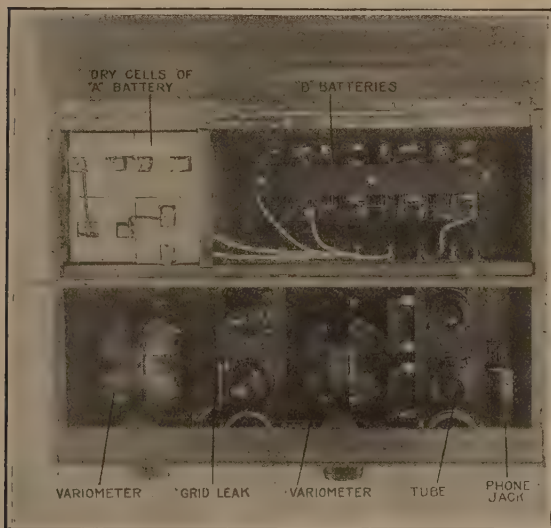
radio-frequency units, the latter being by far the more preferable. Indeed, one stage of properly constructed tuned radio-frequency is generally equivalent to two stages of untuned or fixed radio-frequency. Furthermore, untuned or transformer-coupled radio-frequency generally requires a potentiometer adjustment for clearing up the signals, and this means a troublesome manipulation which goes a long way towards offsetting the additional controls for the tuned radio-frequency steps or stages. The tuned radio-frequency stages generally make use of fixed couplers with a variable condenser across one of the windings for regulating the wave length, or the so-called phusiformers, which are the equivalent of a close-coupled two-circuit aperiodic tuning coil.

THE RADIODYNE RECEIVER

Among the more popular forms of radio-frequency receivers is the radiodyne type, which is somewhat similar in general idea to the popular neutrodyne. The radiodyne makes use of fixed inductances and transformers, with variable condensers to obtain the necessary wave-length changes. The Atwater-Kent radiodyne receiver is an outstanding example of this type. With its fixed inductances and transformers and its three variable condensers, it enables the radio enthusiast, no matter how inexperienced he may be in radio matters, to bring in long-distance stations loudly and clearly. It is essentially a loud-speaker receiver, being too powerful for headphone reception. Furthermore, there is no provision made for cutting in the telephone receivers after the detector, hence the telephone receivers must be used with the two stages of audio-frequency amplification.

The popularity of the Atwater-Kent radiodyne is due

in large measure to its simplicity. The three condenser dials are always set to the same readings for the reception of a given station. Once the various stations are charted, with the three dial readings jotted down for each station, the operator can instantly tune in



Looking down into the cabinet of the receiving set shown on page 139. Note the two variometers, the four tubes, and the dry batteries in their respective compartments. This arrangement makes the receiver entirely self-contained, with the exception of the loud-speaker, as compared with other receiving sets making use of a storage battery.

for any desired station, just as in the neutrodyne receiver.

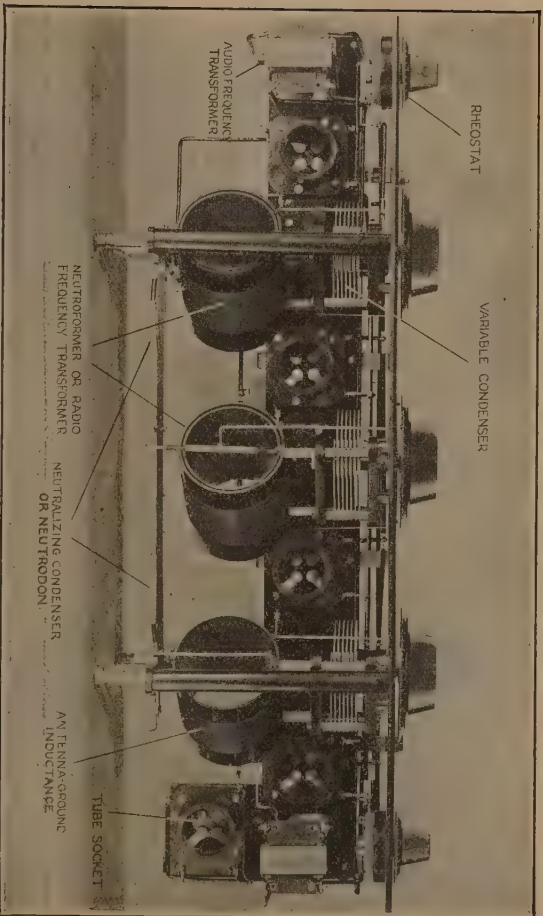
A potentiometer is provided with the Atwater-Kent

radiodyne receiver for the purpose of clearing up the signals. This and the other components are mounted on a neat board, with all the apparatus plainly in view. This table mounting is highly popular, especially with the attractive furniture now available to take such a receiving set.

THE POPULAR HAZELTINE NEUTRODYNE

It is useless to deny that the most popular receiving set today is the neutrodyne, which has been developed by Prof. L. A. Hazeltine of the Stevens Institute of Technology. He named his receiver the "neutrodyne" because the capacity coupling of the radio-frequency amplifying tubes is neutralized. The circuit consists essentially of a tuned radio-frequency amplifier which is stable, neutralization being affected by small capacities from grid to grid of successive tubes, these small capacities being known as neutrons. With the neutrodyne receiver there are no squeals and distortions such as are encountered in some radio-frequency amplifiers which break into oscillation unless they are prevented from so doing by potentiometer adjustment.

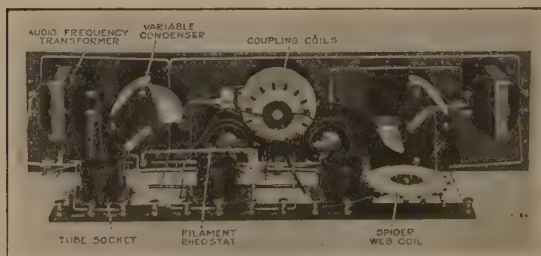
The neutrodyne receiver is distinguished by its three uniform tuning dials, and one or two rheostat controls for the filaments of the detector and amplifiers. The three dials control the wave-intercepting system and the first and second radio-frequency stages or neutrostages. Not only is the neutrodyne receiver exceedingly sensitive and efficient, but it is devoid of the annoying squawks and shrieks which have been so characteristic of radio sets up till quite recently. It gives beautiful sound reproduction, and, what is more, its manipulation is remarkably simple. Indeed, once the positions of the three dials are charted for any



The mechanism of a neurodyne five-tube receiver, in this instance the Freed-Eisemann type. Note the neutroformers and their tuning condensers, as well as the neutralizing condensers or neutrodions. The neurodyne receiver is one of the most efficient receivers in present-day use, and its simplicity permits even the layman to obtain the maximum results.

given broadcasting station, that station can be picked up every time by setting the dials back to the same positions. The adjustment never varies, provided, of course, that the wave length of the broadcasting station remains the same. It is this positive tuning, in marked contradistinction to the "fishing" that generally goes with the usual receiver, that has made the neutrodyne so popular. Practically all neutrodyne receivers include a two-stage audio-frequency amplifier, so that they can be connected directly with a loud-speaker. Jacks are generally included so that the operator can plug in for the detector with the two stages of radio-frequency amplification in order to get maximum sensitiveness without extraneous noises of the audio-frequency amplifiers for long-distance head-set reception, or with one or two stages of audio-frequency for loud-speaker reception.

The author has had considerable experience with the Freed-Eisemann neutrodyne receiver and certainly cannot help but mention the excellent results obtained with that outfit. Anyone going from one of the old



One of the present-day receiving sets making use of radio-frequency and audio-frequency for building up the sensitiveness of the receiver as well as the volume of sound derived from the loud-speaker.



Receiving set with fixed transformer-coupled radio-frequency amplification. This particular make of receiver makes use of a neatly machined and finished aluminum panel, which serves as a shield in overcoming any body capacity effects.

regenerative receivers to the neutrodyne type is perturbed at first by the utter silence of the neutrodyne receiver. There is absolutely no noise, no howl, no indication that the receiver is working until the three dials are tuned in, when the signals boom in loud and clear. In fact the author has noticed that very late at night when all the stations are off the air but there is considerable static, one may readily chart the dials for the various wave length settings. The three dials are adjusted until the static is heard loudest, and then charted. Thus the operator knows the relative positions of the three dials for their entire scales.

The Freed-Eisemann neutrodyne used by the author is a factory-built set, as contrasted with so many so-called neutrodyne receivers which are merely assembled by amateur builders. Only too often the neutrodyne is judged by the results obtained with non-factory sets; indeed, the author had already made up his mind regarding the neutrodyne receiver when he received the opportunity of trying out a factory-built set. The

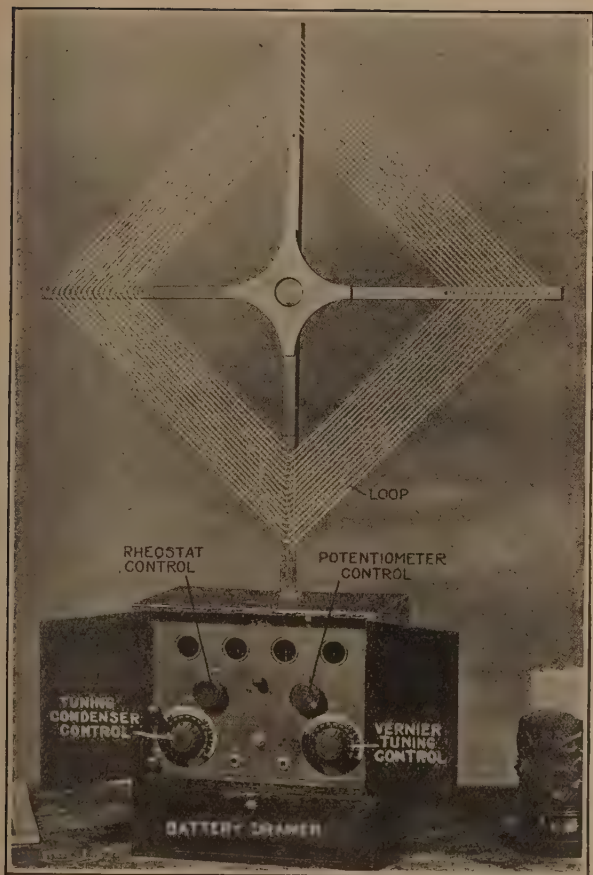
difficulties of balancing up or neutralizing the neutrodyne circuit makes it somewhat difficult for the lay builder to get the best results. Furthermore, with the manufacturers putting out neutrodyne kits, complete with panels which in some instances carry the same engraving as the factory-built sets, the buyer has a difficult task distinguishing between the factory-built product and the assembled set. Some manufacturers overcome this difficulty by some distinguishing label or serial number. At any rate, any severe price cutting on a neutrodyne receiver should be looked upon with suspicion; as often as not, the cut-price neutrodyne is not a factory product, and is therefore apt to be of low quality.

The neutrodyne is an excellent receiving set. Not only is the operation remarkably simple so that anyone can operate it without previous experience or radio knowledge, but the results are astonishing. It is essentially a broadcast receiver, intended for the man who wants to get the radio programs loud and clear with a minimum of trouble. The neutrodyne receiver stands for excellent broadcast reception with radio technicalities left out.

SETS THAT USE A LOOP INSTEAD OF ANTENNA AND GROUND

So far, all the sets described have been intended for operation with the antenna and ground system of wave interception. There are many who prefer to use the loop type of wave interceptor, not only for its convenience but also because of the elimination of considerable static and parasitic disturbances which are experienced with an antenna-ground wave interceptor, more particularly one comprising a long antenna.

It has been pointed out earlier in this work that a loop does not begin to pick up as much radio energy



Loop type of receiving set. In which a compact loop does away with the antenna and ground arrangement. Using dry-cell tubes, this outfit is entirely self-contained except for the loud-speaker.

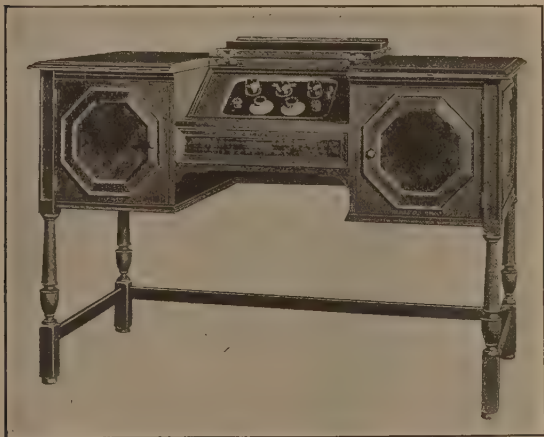
as the usual antenna, and therefore a loop can only be used with a super-sensitive receiver. Hence all the loop types of receivers are costly as compared with those operating on the usual antenna-ground wave interceptor. The simplest, practical loop receiver requires at least five tubes, of which two are for radio-frequency amplification, one as the detector, and two for audio-frequency amplification. Even so, such a receiver still lacks the necessary amplifying power to operate over long distances as a regular performance.

The necessity for several stages of radio-frequency amplification and audio-frequency amplification to bolster up the weak radio energy intercepted by the loop, has brought about the ingenious reflex technique, which means the use of a set of tubes first for radio-frequency amplification, then, secondly, passing that built-up radio-frequency energy to the detector for conversion into audio-frequency energy, and, finally, passing back or "reflexing" that audio-frequency energy through part or all of the original set of tubes. Thus the tubes are made to serve twice, which means that a lesser number of tubes is required for a given task.

THE REFLEX RECEIVER WHICH MAKES THE TUBES WORK TWICE AS HARD

Reflex sets are quite popular today, especially in connection with loop reception. One of the better known loop sets has four vacuum tubes, yet secures the results of six tubes. This saving of two tubes is accomplished by using the second and third tubes as amplifiers simultaneously for both the radio and the audio-frequency amplification. A crystal detector is employed, because of its quiet and faithful repro-

duction of the radio signals. Crystal detectors are employed in many of the present-day reflex receivers, since they give better results than the vacuum tube detector. There is ample energy available to operate the crystal detector in such a circuit, as compared with the ordinary crystal type receiver in which the radio energy is brought directly to the detector without radio-frequency amplification.



One of the more elaborate offerings of radio furniture. Radio receiving sets are now available in many different types of period cabinets, blending in with the decorative scheme of any home.

The reflex idea has been worked out in several ways. Sometimes all the tubes are made to work twice; other times only part of the tubes are used for the two kinds of amplification; sometimes a crystal detector is employed, and then again the vacuum tube detector

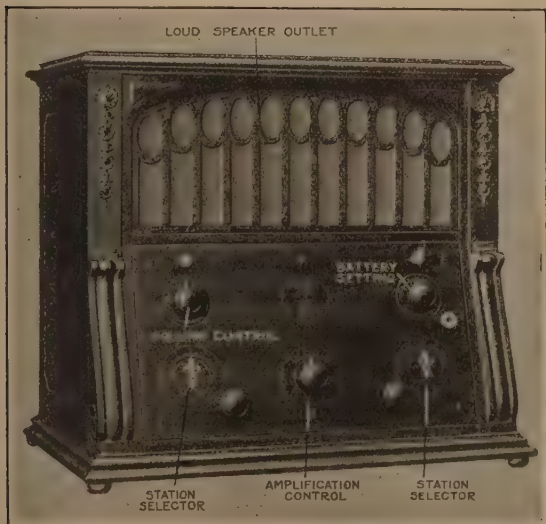
is given the preference. Perhaps the highest development of reflexing will be represented for sometime to come by the Grimes Inverse Duplex system, in which the incoming signal reaches the first tube where it is amplified at radio-frequencies and passed to the second tube, where it is once again amplified at radio-frequencies. From the second radio-frequency tube it is passed to the third or detector tube to be converted into audio-frequency energy, this energy being passed back to the second radio-frequency tube which now acts as an audio-frequency amplifier, and again to the first radio-frequency tube which acts as the second stage of audio-frequency amplification. It must be quite obvious why this circuit is called "inverse" reflex.

There are several variations of reflexing, both in the ready-made receivers and those made up from parts. The simplest reflex receiver comprises a single tube which acts as radio-frequency and audio-frequency amplifier, and a crystal detector. Then there are the more elaborate reflex receivers using a number of tubes. Because of the marked sensitiveness of the multi-tube reflex sets, they are generally used in conjunction with a loop, although they can also be used with an antenna and ground for long-distance work, when local stations are off the air. If local stations are received with the usual antenna, the signals will be too powerful and will virtually paralyze the reflex receiver. Only the single tube reflex should be used with a standard antenna.

THE SUPERDYNE CIRCUIT

Among the recent receiving circuits to be introduced is the superdyne which has attracted a good deal of attention and much favorable and impressive comment. This is fairly simple to tune, and gives excellent results

for the number of tubes involved. The designers of this circuit, which is now available in the form of special parts or as a complete receiver, have endeavored to eliminate the capacity feed-back of the vacuum tubes, and to eliminate the difficulty of securing a



Typical "furniture" radio set, with self-contained loud-speaker and dry batteries. Sets of this kind are finding their way into the living room of the best American homes.

resonant plate circuit. The plate reactance or inductance in the superdyne is reversed so as to feed the energy back to the grid circuit in the reverse direction, or, to put it another way, negatively. It has

been found necessary to give just enough negative feed-back to offset the positive capacity feed-back of the tube. This arrangement will stop oscillation and make it possible to secure absolute resonance between the grid and plate circuits. Resonance has thus been secured with the maximum impedance in the plate circuit, which means that the voltage impulse has been built up.

THE ACMEDYNE CIRCUIT

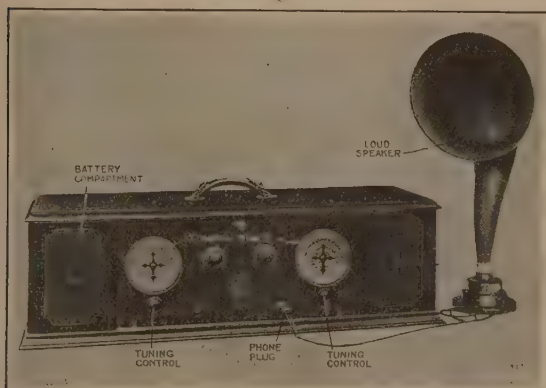
On the heels of the famous neutrodyne circuit has come an improved radio-frequency amplifier developed by Lester O. Jones and called the acmedyne. This is a tuned radio-frequency circuit which is remarkably stable because of its variable coupling feature, compensating inductance, and variable compensating condenser. These features insure against excessive grid potential and provide for a perfectly balanced circuit, even when all circuits are exactly tuned. Tuning is sharper in each stage of the acmedyne because of the design of the secondary of the vario-transformer used. This secondary is theoretically a variometer, and tunes inductively. Thus the designer has reduced distributed capacity to a minimum, and it is this feature which makes the circuit tune sharper and give greater amplification than is found in many other radio-frequency circuits. The acmedyne is essentially a long-distance receiver, bringing in stations over 1,500 miles distant on a loud-speaker with only a single stage of audio-frequency amplification. The radio broadcast signals reproduced by this circuit are virtually free of distortion and therefore of high quality. The acmedyne is standardized as a four-tube outfit, although the results obtained are better than those obtained with the larger part of the five-tube circuits.

The acmedyne circuit is available in the form of the

special vario-transformers and compensating condensers, which can be incorporated with other parts to make a complete receiver, or as a completely assembled receiver ready to use.

THE SUPER-HETERODYNE CIRCUIT

Although the super-heterodyne receiver has only of late come into extensive use, it is by no means a new



Semi-portable type of Armstrong super-heterodyne receiver with loud-speaker. The dry cells for the filament current and the B-batteries are carried in the compartments of the cabinet. The set contains a loop for intercepting the waves.

circuit. Its genesis goes back to the days of the World War, when Major E. H. Armstrong was hard at work on the problem of military radio communication. However, the present-day super-heterodyne receivers which are now being offered in the form of parts and complete sets, represent a number of marked improve-

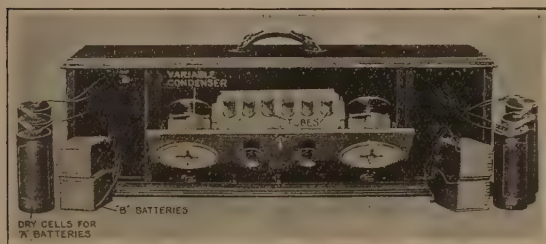
ments over the earlier Armstrong super-heterodyne receivers.

The super-heterodyne circuit is remarkable in more ways than one. First of all, it is super-sensitive, which means that it operates with a small loop and reaches out for DX stations in an amazing manner. It is by no means unusual for a super-heterodyne to pull in stations 2,000 miles away on the loud-speaker, and with good conditions this distance can be extended to 3,000 and even 4,000 miles, these increased distances being obtained preferably with the head-set. Then again, the super-heterodyne receiver is quite simple to operate, there being only two controls which require adjustment. Still further, it is compact, especially when provided with a self-contained loop. It is highly selective, despite its supersensitiveness, because of the method employed which first detects the signals and then plays them against a local wave or frequency, after which it amplifies the "beat" note obtained and re-detects the signals with a second detector followed by audio-frequency amplification. It is this arrangement—the double detection or "beat" note reception—that is peculiar to the super-heterodyne.

The many problems of radio-frequency amplification are happily solved in the super-heterodyne circuit. Instead of using tuned radio-frequency amplification, with its multiplicity of controls, which is necessary for the best results in the usual types of receiving circuits, the super-heterodyne makes use of fixed radio-frequency amplification and therefore eliminates that many controls. However, the fixed radio-frequency amplification in this case is of such frequency or wave length that it becomes possible to obtain high efficiency with fixed transformers.

Making use of fixed so-called intermediate frequency, then, the first step in the super-heterodyne is to detect

the incoming signal in much the usual manner. Here a control is used for the wave length adjustment of the first detector. When the incoming wave is impressed on the detector, the detector output is played against a local wave or frequency generated by a tube known as the oscillator. The oscillator is provided with a second control, so that the frequency or wave-length of its wave may be changed at will, although the potential or amplitude of that wave remains the same. Now, as the detector output and the oscillator wave come together, there is set up a new wave, which is the



Semi-portable type of Armstrong super-heterodyne receiver opened up to show the tuning condensers, the tube rack with six tubes, and the two kinds of dry batteries employed to operate the tubes. The wave-intercepting loop is at the back of the cabinet, and does not show in this view.

difference between the two previous waves, and is known as the "beat" note. This wave or "beat" note has impressed on it all the latent sound characteristics of the intercepted radio wave, and it is passed through several stages of fixed transformer amplification at intermediate frequency until it reaches the second detector, where it is converted into audio-frequency energy and passed through audio-frequency amplifiers in the usual manner.

The super-heterodyne receiver is obtainable in the

form of parts or as a complete receiver. Although this circuit is quite critical in construction, there is no reason why it cannot be constructed with the excellent parts and complete kits now available, by those who prefer to build their own set.

For radio enthusiasts who prefer to buy the complete set, there are several models of super-heterodyne receivers now available. The foremost of these are of the self-contained type, making use of dry-battery tubes and compact loops within the cabinet.

One thing is certain, the radio beginner will obtain as good results with the present-day super-heterodyne receiver as the expert radio operator using some other type of circuit, so simple is the manipulation of this circuit.

AND THE MECHANICAL CONSIDERATIONS

Having disposed of the radio characteristics of the various circuits now available, it may be well to say a word regarding the mechanical characteristics.

Receiving sets may be had in the form of neat cabinets with a front panel on which the various controls are mounted, or in the form of a board with the various parts and wiring entirely exposed to view. The latter style is known as table mounting. At least one manufacturer has specialized in table mounting, and his goods have met with wide favor.

Whether to use the cabinet style or the table mounting is largely a matter of taste. There are advantages claimed for both styles. The cabinet mounting protects the parts from injury and certainly keeps the dust off them, while the table mounting presents an attractive appearance and lends itself to experimental changes in the wiring and the placing of the components. Furthermore, of late there have been developed



Combination radio receiving set and phonograph. This arrangement is gaining in favor, and several phonograph manufacturers are now offering combination machines.

certain pieces of furniture which take the standard table mounted receivers so that we now have the advantages of the cabinet type while retaining those of the table mounting.

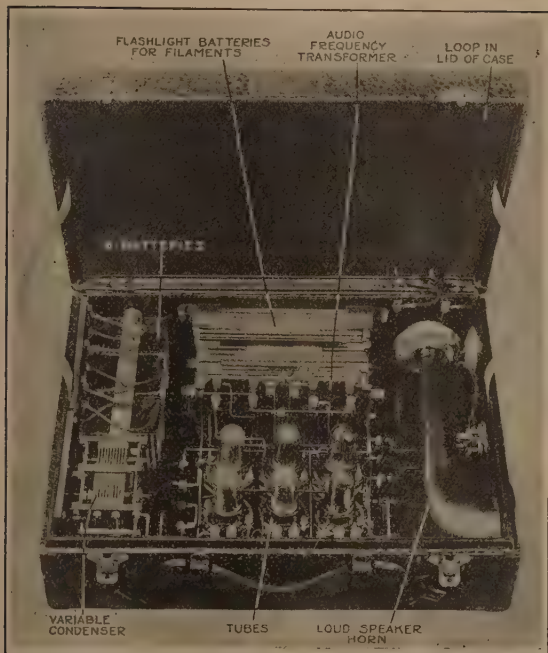
If a receiving set is intended mainly for experimental use, the builder may simply mount the instruments on a panel and a base-board, without the use of an enclosing cabinet. In fact, the usual practice is to

construct a receiver on a standard sized panel with a heavy baseboard, and after the receiver is complete and functioning properly the assembly is placed in a standard sized cabinet.

Today, with radio accepted in the home as a necessary means of entertainment rather than an experimental toy for the tinkering member of the household, there is more and more demand for the dressing up of the radio set. Radio has now been admitted into the living room of the home, instead of being relegated to some obscure corner to be heard but not seen.

Thus we have more and more furniture radios, so called, coming into use. The tendency in many quarters is to put up the radio sets in neat pieces of furniture, with all the radio mechanism hidden from sight. Even the loud-speaker horn is concealed from view. The development here is very much along the same lines as the phonograph, which was converted from an unsightly box with the mechanism in plain view and harnessed to a huge tin horn, to the present-day cabinet type which harmonizes with the other furnishings of a given room.

Furniture radio is an excellent idea and is bound to grow in popularity. In fact, the ultimate in radio receivers is probably going to take the form of a combination phonograph and radio set in a beautiful console cabinet. Already, several phonograph manufacturers are turning out these combination machines. However, the ultimate which the author has in mind is a machine in which the relatively crude phonographic reproducer, which makes use of mechanical amplification and a heavy needle, will be replaced by a delicate electrical reproducer which will send its pulsating electric currents through the same amplifier and loud-speaker as the radio end of the combination. In this manner, the phonograph will gain considerably



Portable radio set mounted in a special carrying case of the same size as the usual overnight bag. Note the six tubes for radio-frequency, detection, and audio-frequency purposes, also the batteries and the loud-speaker. The loop is concealed in the lid of the case.

through its partnership with radio. The present combination machines, while excellent at this time, are bound to be looked upon as improvisations in the light of future developments.

The furniture radio sets are entirely self-contained,

with the batteries and loud-speaker all in one cabinet. In fact, this type has had considerable influence in making the dry-battery vacuum tube so popular, doing away, as it does, with the messy and troublesome storage battery.

With furniture radio there is but one word of caution: remember, fine furniture does not contribute a single thing to radio efficiency. There may be a temptation on the part of some manufacturers of furniture radio to spend more money on appearances and less on the radio end. This must be guarded against by the radio public. After all, it is the radio set itself, whether it is dressed up in an imitation mahogany box or in a carved period type cabinet, that does the work. Fortunately, most of the phonograph manufacturers are using standard radio receivers in their combination machines, so that the buyer is assured of a good radio receiver.

CHAPTER V.

THE VACUUM TUBE—WHAT IT IS AND WHAT IT DOES

THE vacuum tube is the most interesting as well as the most useful device which has been developed during the progress of the radio art. Without going into the interesting history of this device, it may be said in a general way that Edison originally discovered the basic principle involved; an English scientist, Flemming, applied that basic principle to radio reception; DeForest, an American radio experimenter and inventor, introduced an additional member in the vacuum tube which increased its usefulness beyond measure; and scores of inventors and engineers have since worked out many uses for the vacuum tube in and out of radio.

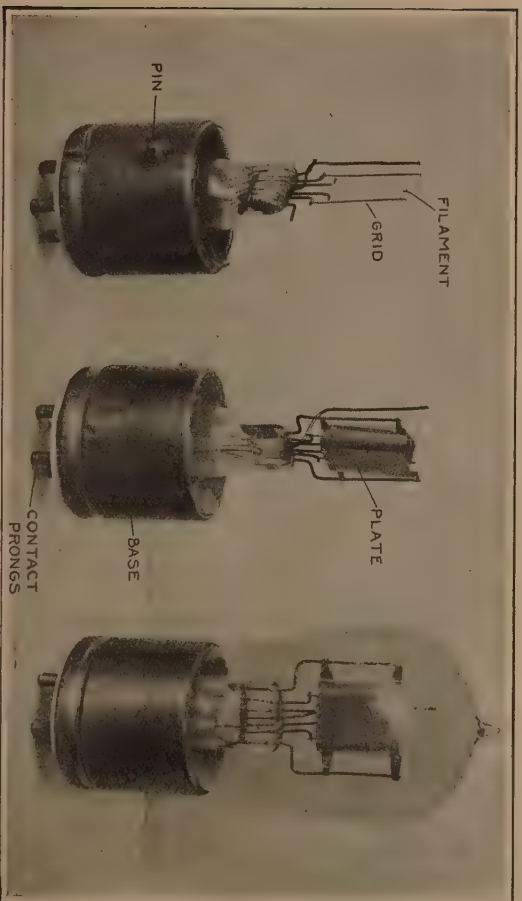
It was that great inventor, Edison, who originally discovered the peculiar behavior of an incandescent lamp filament in the vacuum of the usual electric lamp. Certain observations led him to insert an extra wire in a lamp bulb, and he soon discovered that when a lamp filament is cold, no current can be passed across the vacuum between the filament and the extra wire

or other electrode, known as the "plate," placed in the same bulb. However, the moment the filament is brought up to incandescence, a current can be passed across the vacuum gap between the hot filament and the "plate," but the current can only be passed in one direction, since this device is a uni-directional or unilateral conductor of electricity. Thus the vacuum tube, as this device is called, may be used to rectify alternating current of any frequency, since it allows the current to flow in one direction only, permitting all the positive impulses to flow through and shutting off the negative. The alternating current now becomes pulsating direct current. This principle can be applied in the rectification of commercial current, for use in recharging storage batteries, or in the rectification of radio signals so that they may be converted into audible currents.

What really takes place in the vacuum tube is subject to a good deal of theorizing, and bulky volumes have been prepared on the subject. It is not within the province of this book to deal with intricate theories, but suffice it to state that the white hot filament gives off millions of infinitesimal yet electrically charged particles known as electrons. These electrons, or negatively charged particles, travel from the filament to the relatively cool and positively charged "plate," and thus form a bridge over which one-way traffic of outside electric current is permitted. Depending on the volume of electrons, the bridge is of a greater or less capacity, and therefore accomodates more or less traffic.

THE DIODE OR TWO-ELEMENT TUBE AND THE TRIODE OR THREE-ELEMENT TUBE

A vacuum tube which comprises the filament and the "plate" is known as a diode or two-element tube. This



Typical vacuum tube of the standard three-element or triode type, showing the elements of the tube. The grid and filament elements are shown in the left-hand assembly, the plate in the center assembly, and the entire tube in the third.

type of tube is used in certain kinds of current rectifiers employed for the recharging of storage batteries on alternating current circuits. In the smaller sizes this tube is now used as a detector in preference to the usual crystal detector, especially in reflex circuits, because of its absolute stability, although in sensitiveness it hardly surpasses the best of crystal detectors. Earlier in radio history the two-element tube was extensively used as a detector.

It remained for the well-known American experimenter and inventor, Lee DeForest, to introduce a third element in the vacuum tube, known as the "grid." Referring to what has already been stated, it will now be noted that there is a traffic officer, so to speak, who decides how much traffic shall pass over the electronic bridge of our vacuum tube. The traffic officer is none other than the "grid," which is nothing more formidable than a length of wire arranged as a cage about the filament or as a lattice-like structure interposed between filament and plate. The electronic flow passing from the hot filament to the cold plate, must filter through the spaces between the grid. And it so happens that any charge which is impressed on the grid immediately affects the electronic flow, either allowing a greater electronic flow or a lesser one. This, in turn, affects the passage of the external current being passed over the electronic bridge, between the filament and the plate.

The three-element or standard vacuum tube is a most sensitive device. The weak charge impressed on the grid controls faithfully and instantly a comparatively powerful current flowing between the filament and the plate. In this manner it becomes possible to control a strong current by means of a weak one. The energy of incoming radio waves is led to the grid, where it serves to control the electronic flow; and the electronic

flow, in turn, controls the passage of current through the tube to the telephone receivers or amplifying equipment.

The vacuum tube can be used for a variety of purposes. It is a rectifier of alternating current; that is to say, it converts alternating current of almost any frequency and of any strength within its capacity into direct current. It can, conversely, transform direct current into alternating current of a wide range of frequencies, when arranged as an oscillator. It permits of controlling a powerful current by means of a weak current; indeed, it is this feature which is the basis of the usual detector; and also the amplifier of the receiving set. This characteristic is also the basis of the telephone repeater now employed in long-distance telephony; vacuum tubes permit of rebuilding attenuated telephone currents at any desired interval along the line, so that a greater distance may be spanned. In transmitting, the vacuum tube is again used for amplifying purposes; as already explained earlier in this work, the vacuum tube, or rather a series of such tubes, serves to build up the delicate voice currents until they have sufficient power to operate the powerful transmitter, this technique being known as modulation.

Of vacuum tubes, there are many kinds. There are small tubes intended for portable radio receivers and those in which dry cells are to be used exclusively. There are larger tubes for receiving sets operating with a storage battery. There are still larger tubes intended for small transmitters and for the modulation end of large transmitters. And again we have larger tubes intended for broadcast transmission. Finally, there are still larger water-cooled tubes with power rating running into many kilowatts, intended for long-distance radio telegraphic communication.

THE CHOICE OF A RECEIVING SET TUBE

Three main considerations enter into the choice of a tube for reception: First, the purpose for which the set is to be used—broadcast listening for the enjoyment of radio programs; experimentation on apparatus and circuits; or long-distance code reception. Secondly, the type of set in which the tube is to be employed—the electrical circuits involved, the number of tubes used, and whether a loud-speaker is to be operated or simply head-phones. Thirdly, whether a storage battery or dry battery is to be used, and if the latter, whether the battery will consist of the standard dry-cells or the small flash-light dry-cells, for the operation of the tube filaments.

THE DIODE OR TWO-ELEMENT TUBE

The simplest type of vacuum tube is the diode or two-element tube, consisting of the usual filament and a plate element. This tube is available in several different styles, all serving the same end. Such a tube operates on a filament battery of several dry cells, but requires no plate or "B" battery. It takes the place of the usual crystal detector in a plain circuit or in an elaborate reflex circuit. It has the advantage of noiseless operation as compared with the three-element detector tube, but it is questionable whether such a tube has a decided advantage over a good crystal detector, so far as sensitiveness is concerned. However, the diode tube is stable in its operation and requires no adjustments such as are necessary with the usual crystal detector.

After all, the diode tube has a very limited application in present-day radio, as compared with the triode or three-element tube.

THE WD-11 AND WD-12 TUBES—ESSENTIALLY DRY-CELL
TUBES

In order to meet the demand for dry-cell-operated tubes, leading radio manufacturers brought out the WD-11 tube early in the present radio broadcasting era. This tube has a rated current consumption of 0.25 ampere, and the terminal voltage 1.1 volts. It is a "hard" tube, especially suitable for amplification, although it is also a good detector. It will take a plate potential of anywhere from $22\frac{1}{2}$ to 150 volts, depending on the use to which it is put.

Some time after the introduction of the WD-11 tube, the manufacturers brought out the WD-12, which has the same electrical characteristics but varies from the former only in the matter of the base. The WD-11 has a special base which calls for a special socket, while the WD-12 has the standard base so that it can be used in any standard socket.

The WD-11 and WD-12 tubes will operate on a single dry cell for each tube. The author's personal experience with these tubes indicates that if a single dry-cell tube set is used two hours a night, a fresh dry battery should last from 50 to 60 hours of actual use. In other words, if the set is used every night this would give a life of about a month to the dry-cell which, in terms of maintenance expense, would amount to 40 cents per month. This is much lower maintenance cost than that of a storage battery, which must be recharged at least once a month and preferably twice a month at a minimum cost of \$1.00 per month.

The WD-11 and WD-12 tubes more than any other factor have been responsible for the inexpensive single-tube sets which now abound in such great numbers. These tubes have made radio enjoyment possible for many in modest circumstances, who could ill afford

to invest in an expensive storage battery and its re-charger, called for by certain tubes.

THE TINY UV-199 AND C-299

Then there are the UV-199 and C-299 tubes, requiring a minimum of filament energy, although calling for three dry-cells in series as the battery. In fact, these tubes use only .18 of a watt, or about one-eighthieth the power consumed by a 40-watt electric lamp.

The bulb of either of these tubes which, by the way, are built to the same specifications, is of small size, and a special base and socket suitable for such a small tube, are employed. On account of the small size of this tube, the capacity between electrodes is lower than in most other tubes; but when the UV-199 or C-299 is used in a standard socket the capacity of the adapter employed added to the capacity of the tube makes it practicable without changing the circuit. This tube is particularly suited for portable sets in which it is necessary or desirable to use ordinary dry-cells or flashlight cells for filament operation.

The small electrical capacity between the electrodes makes this type a very satisfactory tube for radio-frequency amplification. This type does not require critical adjustment of plate voltage, and tapped plate batteries are not really necessary, whether the tube is used as a detector or as an amplifier.

At this point it is well to explain the meaning of the different designations of the "UV-" and the "C-" series of tubes, which are exactly the same as regards design and operating characteristics. The "UV-" series of tubes are marketed through the Radio Corporation of America, while the "C-" series are marketed through the Cunningham organization; but both series, tube for

tube, are the same, being made according to the identical specifications and in the same factories.

THE UV-200 AND C-300

These tubes are particularly desirable for the skilled radio experimenter interested in code work and reception over great distances. They are not suitable for dry-cell operation because the filament requires one ampere at five volts. Obviously, the UV-200 or C-300 tube is intended for storage battery operation.

The action of either of these tubes is very critical with respect to filament voltage and plate voltage, and is not uniform between different tubes of the same type or as constant in any tube as in the case of the high-vacuum tubes, such as the UV-199, C-299, UV-201-A and C-301-A. This type of tube is known as a "gassy" tube or "soft" tube, as distinguished from the high-vacuum tubes which are sometimes called "hard" tubes. It is essentially a detector tube, and is quite unsuitable as an amplifier.

The UV-200 or C-300 is very sensitive to weak signals, especially spark and modulated CW signals, when skillfully handled by experienced operators in a circuit particularly equipped for the proper voltage operation of filament and plate. This type of tube is not recommended for audio- or radio-frequency amplification and should never be used with a plate voltage greater than that obtained from a 22½-volt B-battery at full voltage. The B-battery used with such a tube should be of variable kind, with taps for various voltages. The usual UV-200 or C-300 tube will be found to work best with a plate voltage anywhere from 15 volts to 20 volts, the various voltages being tried with a given tube until the best results are obtained. For the best results a potentiometer is used to regulate the plate voltage.

This type of tube requires a little patience and skill in its adjustment for the proper reception of weak signals. Under certain conditions it has a tendency to be slightly more noisy in operation than the high-vacuum tubes which are practically free from such disturbances. For this reason, and because of the absence of troublesome adjustments, the high-vacuum or "hard" tubes have come more and more into favor in modern receivers. Indeed, "hard" tubes are recommended exclusively by most manufacturers of receiving sets.

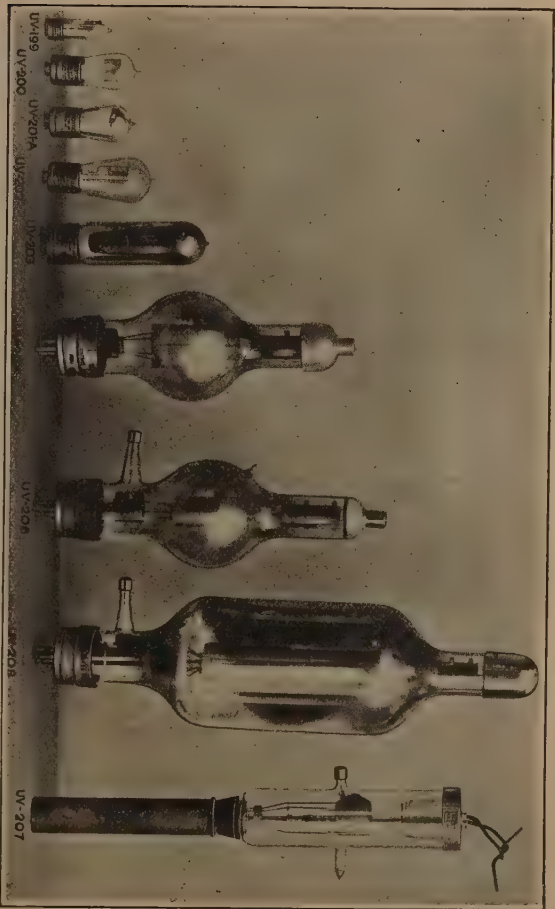
THE UV-201-A AND C-301-A

These tubes are powerful amplifiers, inherently better than the UV-199, and are particularly suitable for loud-speaker operation. They are designed to give the best possible amplification for general use, their amplification property not being sacrificed to any extent to give a minimum of filament energy.

The operation of these tubes is almost free from variations caused by slight changes in plate and filament voltage. Accordingly, they are quiet in operation and have a longer operating life than any of the tubes already mentioned. They are equipped with a standard base and thus fit in many sets already constructed, unless they have been made especially for UV-199 or C-299, or the WD-11 or C-11 tubes.

The filaments of the UV-201-A and C-301-A require a much greater amount of current for their operation than does the UV-199 or C-299, but nevertheless the former tubes can be operated from dry-cells in the case of one or two tubes used only a few hours per day, at a lower expense than with the use of a storage battery.

As an audio-frequency amplifier, these tubes are somewhat superior to the UV-199 and C-299. As a detector, the UV-201-A and C-301-A are about the same



The Radiotron family of vacuum tubes, arranged according to power. At the left is the diminutive UV-199 type detector and amplifying tube employed in dry-cell receiving sets, followed by the UV-200 and 201-A storage-battery receiving tubes. UV-202 is a 5-watt transmitting tube. UV-203 is a 50-watt tube, while UV-204 is a 250-watt tube. UV-206 and UV-208 are transmitting tubes. UV-207 is a high-power water-cooled transmitting tube.

in response as the UV-199 or C-299 and are to be recommended over the UV-200 for most general purposes, except in equipment specifically designed for the latter tube as regards potentiometer adjustment for plate voltage and very fine adjustment for filament voltage.

The UV-201-A and C-301-A are ideal for a one-tube set employing dry-cells or for a multi-tube set when a storage battery is available for filament operation. Critical adjustments of filament and plate voltages are not required and it is not necessary to have taps on the plate batteries.

Although the capacity between the electrodes of the UV-201-A and C-301-A is somewhat greater than the UV-199 and C-299, their greater inherent amplification makes them just as satisfactory in most radio-frequency amplifier circuits.

The UV-201-A and C-301-A take the place of the old UV-201 and C-301 tubes, which were "hard" tubes made up with plain tungsten filaments instead of the so-called activated filaments of the present tubes, and required over an ampere of filament current as compared with the one-quarter ampere draw of the present tubes. The present tubes are far more efficient than the old tubes which they replace.

THE DeFOREST TUBES

The DeForest tubes or "audions," to give them their original name, are of special interest because it was Dr. Lee DeForest who introduced the three-electrode vacuum tube which makes present-day radio possible.

The DV-3 DeForest tube is intended for dry-battery use. This tube is designed to consume a very small amount of filament current. It operates at a filament potential of three volts and consumes a filament current of six one-hundredths of an ampere. It should always be operated with a variable filament rheostat



Two DeForest vacuum tubes or audions. The tube at the left, Type DV-3, operates on three dry cells, while the tube at the right, Type DV-2, is a low-amperage storage battery tube.

connected between the filament and the dry battery. The purpose of this rheostat is to maintain the filament voltage at its proper value over the duration of the life of the dry battery.

The DeForest DV-3 has an activated filament giving an unusually high flow of electrons. Indeed, this tube has much the same characteristics as the UV-199 and C-299, although it is provided with a standard base

of bakelite. It is remarkably free from microphonic noises, which is a highly desirable characteristic.

The DeForest DV-2 is intended for storage battery operation, and was developed for use in all usual circuits, including a power amplifier circuit. It operates on a filament potential of five volts or less, and should be used with a variable rheostat between the filament and a six-volt storage battery. The filament consumption is roughly one-quarter ampere, or about the same as that of the UV-201-A or C-301-A, of which this tube is practically a counterpart. The base is standard but is insulated with a special insulating substance which is claimed to make for extremely low electrical loss and a very high electrical strength, and for freedom from moisture absorption. This tube does not require a "C" battery. It has a large output and mellow tone.

THE WESTERN ELECTRIC TUBES—RARE TUBES INDEED

Due to one of the peculiarities of radio patents and licensing arrangements, the Western Electric Company is not licensed to sell to the radio public the various types of tubes which it manufactures, with the exception of one tube, type 216-A, which is sold as initial equipment and for replacement in connection with the loud-speaker equipment made by that company. Yet the fact remains that the Western Electric Company has developed many types of excellent tubes which would be a welcome addition on the market.

At any rate, even though the Western Electric tubes are not available on the everyday market, there is a certain amount of interest in these tubes. They have been sold in limited numbers by radio stores engaged in disposing of war-time supplies.

The type J Western Electric tube is popularly known as the VT-1 from its Signal Corps designation. It is

intended primarily as a detector tube, although it can be used as an amplifier. It operates on a normal filament current of 1.1 amperes, and a normal filament voltage of 2.0 to 4.0 volts. The normal plate potential is 17 to 40 volts. The filament is oxide coated and burns very dull red. The filament current should not be allowed to exceed 1.3 amperes, for otherwise the useful life of the tube will be materially shortened. This tube represents exceedingly neat construction, quite characteristic of Western Electric tubes.

The type E is popularly known as the VT-2. It was designed as a power tube to generate and modulate radio-frequency oscillations. It may also be used as an amplifier. The normal filament voltage of this tube is 1.35 amperes. The normal filament potential is 6.5 to 7.5 volts. The normal plate voltage (with zero grid voltage) is 200 volts. If the grid is maintained at a negative potential, the plate potential can be safely raised above the value given by an amount equal to the product of the amplification constant and the negative grid potential. The plate voltage used with the grid at 20 volts negative is 350 volts. If the filament current is allowed to exceed 1.4 amperes, the useful life of this tube will be materially shortened.

The type 216-A tube is used in the Western Electric power amplifier unit which operates the large Western Electric loud-speakers. It is designed for use as an amplifier and is much better for this purpose than either the type J or type E tube. The filament is designed to secure the necessary electronic emission with low filament temperature. This feature ensures, under normal operating conditions, long life and minimum filament power consumption. The normal filament current is obtained with a potential of 6 volts at the terminals of the amplifier. With normal current the filament should glow dull red, and it goes without saying that the filament should never be turned up bright.

The normal filament potential is 6 volts, and the normal plate potential 100 to 130 volts.

The type N tube is popularly known as the Western Electric peanut tube. Indeed, it is the true peanut tube, although other tubes have been erroneously referred to as peanut tubes by the uninformed. This type N tube was developed to require a minimum amount of power for the filament circuit, so that a dry-cell can be used for this purpose with reasonably long life. It is suitable as a detector, radio-frequency amplifier, or audio-frequency amplifier within the limits of its power output. It is an exceedingly small tube—the smallest tube extant, for that matter—and has a special base which calls for a special receptacle.

THE LESSER-KNOWN TUBES

During the recent past, especially since the expiration of certain basic tube patents, numerous brands of new tubes have appeared on the market, these being the products of independent manufacturers. Some of these tubes are of the same general appearance as the standard makes, and may be mistaken for same by the unwary buyer who fails to look for the usual distinctive labels.

Certain of the independent tubes are quite satisfactory, while others are not. In general, these independent tubes run less uniform than the standard makes, which is their greatest drawback. As compared with standard tubes, the main talking point for the independent makes is in their lower prices.

THE MYERS TUBE OF UNCONVENTIONAL SHAPE

One of the lesser known tubes is the Myers tube. This type of tube is quite different from any other tube in that it is constructed along the general lines

of a cartridge fuse and fits into a holder that looks quite like the usual cartridge fuse holder. The Myers tube has a small cylindrical plate, helical grid, and a straight filament. It operates on a filament potential of 4 to 5 volts, and a plate potential of 45 to 90 volts and over.

Myers tubes are known for their high amplifying characteristics due to the unusual design which permits of exceptionally high voltage to be passed from the plate to the filament and still be held under the control of the grid. This type may be operated on plate voltages up to 300 without any fear of breakdown. It is also highly satisfactory for radio-frequency amplification. As a detector, the Myers tubes function on almost any plate voltage from $22\frac{1}{2}$ volts up. The tubes being of extremely high evacuation, they are non-critical in operation. The Myers tubes, which are being manufactured in Canada but are available in this country, are made in two types, namely, the dry battery type, which requires a filament potential of $22\frac{1}{2}$ volts and a current consumption of $\frac{1}{4}$ ampere, and the universal type which operates on three dry-cells or a storage battery, with a filament potential of 4 volts and a current consumption of .8 ampere.

THE DONLE OR SODION TUBE—SOMETHING ENTIRELY DIFFERENT

After several years' research work Harold P. Donle, radio engineer of Meriden, Conn., has developed a remarkable vacuum tube which is now available under the name of the Sodion tube. It varies considerably from standard vacuum tube practice, involving as it does an entirely new principle.

The Sodion is essentially a detector tube and as such it is claimed to possess certain marked advantages over the usual vacuum tubes. It cannot be employed

in regenerative circuits, nor as an amplifier. The Sodion tube utilizes the valuable and peculiar properties of a highly electro-positive or alkaline metal such as sodium, and is highly evacuated. It has a heated cathode or filamentary electrode, and an anode or plate electrode. In other respects it is very different from ordinary vacuum tube detectors, particular points of novelty being the presence of an alkaline metal within the tube and the arrangement of the input electrode. The third electrode is not a grid and is not interposed between the filament and the plate or anode. It is placed behind the filament, is trough-like in shape, and is called the "collector." The details are shown in the accompanying sketch, in which *A* is the anode or plate, *B* the glass bead which holds the elements in place, *C* the collector, *F* the filament, *H* the heater coil, and *S* the glass envelope. This is the tube proper and in actual practice there is another glass bulb or envelope which fits around this tube.

The Sodion tube is remarkably sensitive as a detector and compares favorably with the average hard tube detector with two stages of audio-frequency amplification, as well as with the usual detector tube with full regeneration. The operation of the Sodion is stable and uniform, and it will operate for hours without need of adjustment. No grid condenser or grid leak is required. No storage battery is necessary, as the filament current consumption is less than $\frac{1}{4}$ ampere. Therefore, this detector tube will operate on three dry-cells as well as on a standard 6-volt storage battery.

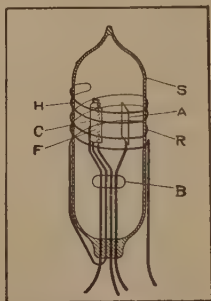
The Sodion cannot be made to oscillate at detection frequency, and therefore never produces beat-note howls or whistles and never interferes with reception by other listeners. Most broadcast listeners have experienced interference from nearby receiving stations of the regenerative type caused by the oscillation of the

detector tube and the radiation of energy from the antenna. This interference is indicated by howls, squeals and at times the complete blocking of incoming signals. Thus the Sodian has been aptly referred to as the Golden Rule Tube, in that it causes no trouble to others.

The purity of tone and clearness of radio telephonic music and speech reproduced through the use of the Sodian detector are unsurpassed. It cannot give the hollow, distorted sounds, characteristic of strong regeneration, yet its excellent tone is maintained at no sacrifice of sensitiveness.

Any radio receiver of the inductively coupled type may be changed over to use the Sodian detector, usually with very little effort. All that is necessary is to provide a low resistance conductive path from filament to collector by short-circuiting the usual grid leak and condenser and to insert a potentiometer for proper control of the Sodian collector potential. The Sodian operates on a filament potential of 3.8 volts and a current consumption of 0.24 ampere or less. It is equipped with a special base, but may be used in standard sockets by means of a special adapter. Special Sodian sockets are also obtainable.

The manufacturers of the Sodian tube have literature fully covering the application of the Sodian tube in special and in existing circuits, hence there is no need of going into details here. This literature may be obtained from the progressive radio dealer, and should be carefully studied before deciding on the sodian tube for a given set.



Schematic details of the Sodian or Donle tube.

THE FILAMENT BATTERY OR "A" BATTERY

The usual vacuum tube requires electrical energy for its filament. It is this electrical energy which heats the filament and causes the latter to give off electrons. The filament is generally operated on a storage battery or dry battery of a voltage slightly in excess of that required, with rheostat or voltage-reducing device placed in one of the leads from the battery so as to bring down the filament voltage to the desired potential.

If dry battery tubes are used, the dry battery should consist of the required number of standard dry-cells if the set is of the non-portable type. It should be remembered that the standard dry-cell has an output potential of about $1\frac{1}{2}$ volts. Thus the $3\frac{1}{2}$ to 4 volt dry battery tubes require three dry-cells connected in series, which means that the center binding post of one cell is used as one terminal of the battery, while the outside terminal is connected with the center terminal of the next, and the outside terminal of this second cell is connected with the inside terminal of the third cell, while the outside terminal of the third cell becomes the other terminal of the battery. In this manner the voltage of one cell is added to the voltage of the preceding cells so that the battery represents the sum of the individual cell voltages. The current capacity or amperage—the volume of flow as distinguished from the potential or voltage—remains the same as that of a single cell, only the potential or voltage being increased by the series arrangement.

Now supposing we are dealing with a $1\frac{1}{4}$ -volt dry battery tube. The filament energy in this case may be furnished by a single dry-cell, or, if longer life is desired from the battery, two or three cells may be used. In this event, however, the cells are connected

in parallel instead of series. That is to say, all the central binding posts are connected together and a lead brought to the filament circuit of the set, and all the outside binding posts are connected together and a lead brought to the other side of the filament circuit. This parallel arrangement gives us the amperage or current capacity represented by the sum of the amperages of the individual cells, while the voltage of the battery is the same as the average voltage of the individual cells. In this manner the voltage remains at about $1\frac{1}{2}$ volts, but the current capacity of the battery is greatly increased. If several WD-11 or WD-12 tubes are to be operated on one battery, that battery should be made up of three standard dry-cells connected in parallel so as to increase the life of the battery and to obtain a steady current by not imposing too great a drain on the battery. Obviously, a single dry-cell could not withstand the current drain imposed by a number of tubes for very long.

For portable sets the small flashlight batteries made up of three cells may be employed, especially in connection with the UV-199 and C-299 tubes. These tiny batteries will operate a single UV-199 or C-299 tube for quite a period.

The inexpensive first cost of the usual dry battery, as well as the convenience and total absence of bother in connection with its operation, has made this type a marked favorite of late. Manufacturers of receiving sets are tending more and more towards the dry battery tube, especially since this type makes it possible to include the battery in the set, thus obtaining a self-contained outfit.

THE CASE FOR THE STORAGE BATTERY

Admittedly the storage battery is messy and troublesome. Containing acid as it does, it is apt to cause

damage if the utmost care is not exercised in handling it. At intervals depending on the use of the set, the storage battery must be recharged. Distilled water must be added from time to time in order to make up for evaporation.

Nevertheless, the storage battery is still widely used because of the greater power obtainable with storage battery vacuum tubes. It is needless to claim every advantage for the dry battery receiver; for, while its numerous advantages are quite obvious and fully appreciated, the storage battery type of set has considerably greater power. This increased power is noticeable in the operation of a three-tube set with loudspeaker, although the tendency of late is to use more and more tubes in the dry battery sets so as to offset the limited output of the usual dry battery tube. Nevertheless, tube for tube the storage battery set has a greater volume, hence its continued popularity with many radio listeners.

Space prevents us from going into the technicalities of storage battery principles and construction. Suffice it to say that a storage battery cell is an assembly of two kinds of lead plates immersed in a solution of sulphuric acid and distilled water, known as the electrolyte. From time to time distilled water is added to the storage battery cell to make up for evaporation, and to keep the plates covered. Each storage battery cell has a potential that varies from 2.2 volts when fully charged, down to 1.8 volts when the cell is discharged. The condition of the charge is determined either by the use of a delicate voltmeter, or by means of a hydrometer which indicates the density of the electrolyte. Usually the latter method is employed, and is therefore described in another chapter dealing with the operation of the receiving set.

A wide range of sizes and styles of storage batteries is available for radio purposes. With the develop-

ment of popular radio there have been introduced special radio storage batteries which differ considerably in internal construction and electrical characteristics from those intended for automobile starting and lighting systems, although the latter can be used if desired. Single cell storage batteries are available for use with the usual $1\frac{1}{4}$ -volt dry-cell tube. Two-cell and three-cell storage batteries of low capacity are available for the $3\frac{1}{2}$ -volt dry-cell tubes, and even for single storage battery tubes. When it comes to operating a number of storage battery tubes, it is best to use a large storage battery with ample capacity to maintain a steady filament energy without frequent recharging.

Storage batteries are rated according to their voltage and their capacity. A single-cell is a 2-volt battery, while a three-cell arrangement is a 6-volt battery. Then there is the factor of capacity—or the volume of current which can be obtained from a given battery without recharging it. Thus we have the small storage batteries with a 20 ampere-hour rating, which means, roughly, that these batteries can deliver 1 ampere of current for 20 hours, 2 amperes for 10 hours, 3 amperes for not quite 7 hours, and so on, within the limitations of the battery. The large storage batteries have ratings of 60-, 80-, 100-, and 120- ampere-hours and more. The higher the ampere-hour rating the less frequent is recharging necessary, but, on the other hand, the larger and heavier becomes the battery, while the price goes up proportionately.

The usual storage battery must be recharged whenever it has given up the better part of its charge. It can be recharged at home by means of a suitable recharging outfit which operates directly on the usual lighting circuit, or it may be sent out to a local storage battery station or garage. In the long run it pays to

recharge the battery at home. Several types of rechargers are described in the chapter dealing with the operation of sets.

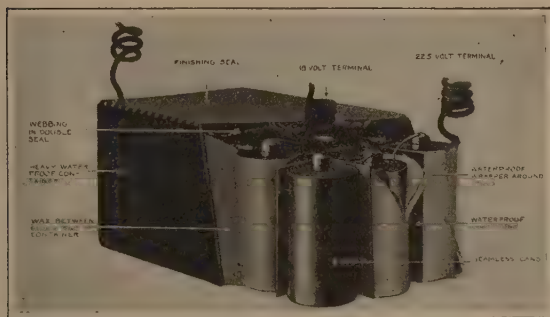
THE "B" OR PLATE BATTERY

Aside from the "A" or filament battery, the operation of the vacuum tube calls for the "B" or plate battery. This battery must be a high-voltage one, although its amperage or current capacity need not be high. Hence it becomes possible to use small dry-cells arranged in series so as to obtain the desired high voltage. In the early days of radio a number of flash-lamp batteries were connected together so as to obtain the necessary potential; but today we have special dry "B" batteries put up in compact units of $22\frac{1}{2}$ -volts, 45-volts, and even in larger units of 150-volts. These "B" batteries not only carry a voltage rating but they are of different sizes. The leading manufacturers now offer their "B" batteries in three distinct sizes, namely, the small, medium, and large sizes, and in different voltages. If the receiving set has but a single tube and is not used excessively, a small "B" battery will do quite nicely. If the receiving set has two tubes and is moderately used, the medium sized "B" battery will do. But if the receiving set contains three or more tubes or is used quite extensively, then the large sized "B" battery should be used. The size of the "B" battery determines its capacity and life, and the larger the battery employed the better results and greater economy will be effected.

Aside from questions of voltage and size, "B" batteries are available in two styles, namely, fixed-voltage and variable-voltage. With the usual run of "hard" tubes now in general use, there is no need of adjusting the plate voltage excepting within wide limits. Thus 45 volts is usually applied on the detector plate,

and 45 to 112 volts or higher on the amplifier plate. When a "soft" detector tube is used, however, the plate voltage is quite critical if best results are to be obtained, and in this case it is best to use a variable-voltage "B" battery, which is provided with tapped cells so that voltages less than the full voltage may be obtained by connecting with the proper tap.

While the plate energy for vacuum tubes is usually supplied by dry batteries, there are small, compact, high-voltage storage batteries available for just this purpose. These batteries are claimed to be more eco-



Constructional details of a 22½-volt "B" battery, showing the individual dry cells and how they are insulated from one another and assembled into a compact battery. The insulation between cells is of the highest importance in the production of a "noiseless" "B" battery.

nomical in the long run, since they can be recharged many times at a far lower cost than that of renewing dry batteries. Furthermore, many of the recharging outfits are arranged so as to recharge these high-voltage storage batteries.

THE "C" OR GRID BATTERY

Another type of battery which is helpful in amplifier circuits in order to obtain the maximum amplification without distortion, is a low-voltage "C" battery connected between the filament and the grid to give the grid a negative potential or "bias." The battery should be connected at the negative or — side of the "A" battery as shown in the lower diagram appearing on the facing page. The "C" battery also reduces the amount of plate current and therefore increases the life of the "B" battery.

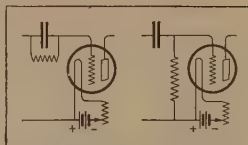
Each type of vacuum tube has different characteristics, but the amount of "C" voltage for different plate values varies from $1\frac{1}{2}$ to 6 volts and is usually specified by the tube manufacturer or the maker of a given receiving set.

The requirements of a "C" circuit call for a steady voltage, a low resistance, and a long-lived battery. Flashlight batteries are often used as "C" batteries, although leading battery manufacturers now put out special sized batteries intended primarily as "C" batteries but also available for the filament supply of small portable sets. An exhausted or low-voltage "C" battery usually produces distorted signals.

The amplification of a set can be materially increased by the careful adjustment of the amplifier potentials. Since the amplifier tube operates on the principle of grid voltage control, the plate of the tube must be maintained positive in order that the electrons emitted by the filament will flow to the plate. The grid is maintained negative. When voltages over 50 are used on the plate, the grid becomes less effectively negative and current flows from the filament to the grid. This produces a voltage drop from the grid to the fila-

ment, which reduces the voltage effective for amplification.

It is in order that the grid may be maintained negative that the "C" battery is introduced. Where plate voltages only of the order of 50 or less are used, sufficient biasing may be obtained by means of a potentiometer, as explained further on.

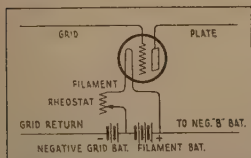


Two methods of using the grid leak and grid condenser with detector tube.

THE GRID LEAK AND ITS RÔLE

A very important member of the vacuum tube detector circuit is the grid leak. Without going into the theory of the grid leak, let it be said that this little member prevents the detector tube from becoming choked up, and works in conjunction with the grid condenser which permits the incoming signals to enter the tube without loss of energy in the grid leak.

There are four major types of grid leaks in general use, namely, the fixed type, with a non-variable high resistance member in a suitable holder; the compression type, in which very high resistance carbon or graphite disks or granules are used under more or



Connections for a vacuum tube when used as an amplifier with "C" battery.

less pressure so as to vary the resistance; the movable lever type in which a lever resting upon the resistance material is made to slide over the surface, thus varying the amount of resistance introduced in the circuit, and the use of a column of mercury or other liquid, more or less

of which is used to obtain the desired resistance.

Each tube has its own grid leak characteristic when used as a detector. It will be noted that the grid leak and grid condenser are used only with the detector tube, and not with amplifiers. According to the engineers of the Radio Corporation of America, the following grid leaks should be used:

With WD-11 and WD-12 tubes.	2 to 3 megohms
With UV-200 or C-300.....	$\frac{1}{2}$ to 2 megohms
With UV-201-A or C-301-A....	2 to 9 megohms
With UV-199 or C-299.....	2 to 9 megohms

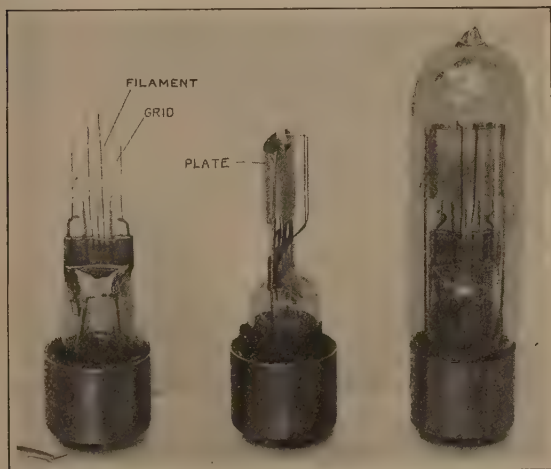
The proper grid leaks for other tubes are specified by the manufacturers of such tubes in their data sheets which they supply.

In some instances the grid leak is connected between the positive terminal of the "A" battery and the grid, and in others it is connected across the grid condenser as shown in the diagram on page 187. Both are correct, but the selection of either is governed by the conditions. The most popular form is that in which the grid leak is combined with the grid condenser. However, in certain types of receivers where the detector tube is preceded by one or more stages of radio-frequency amplification, the other arrangement is used.

As for the grid condenser, there is considerable flexibility in the matter of capacity. Indeed, variable condensers of ingenious design have been worked out for use as grid condensers, but the variable feature seems to be of little if any value in practical operation. Generally, the grid condenser is of .0025 microfarad capacity. Unless the directions accompanying a specific circuit call for another capacity, the .0025 mfd. size should be used for the usual detector tube.

TRANSMITTING TUBES

Transmitting tubes are generally of the three-element type and of the same general design as the receiving tubes, except for their larger dimensions. The



Typical 50-watt transmitting tube, showing the three elements which are similar to those of the usual receiving tube but of larger dimensions.

smallest transmitting tube is the 5-watt type, which is used for short-distance communication and also as a modulator. This same tube also finds considerable application as a power amplifier. Then there is the 50-watt tube, used for moderate-distance communication, and also as a modulator tube. For radio broadcasting, using a 500-watt transmitter, the 250-watt

tube is the favorite, two tubes of this type being used in the oscillating circuit. One kilowatt tubes are also available for high-power transmission.

During the last year or two radio engineers have developed water-cooled tubes handling 20 kilowatts and over. One water-cooled tube has been built which will handle 100 kilowatts. Such tubes are too powerful for the present broadcasting requirements, but they may find an early application in trans-oceanic work, replacing the elaborate alternators now in use.

CHAPTER VI.

AUDIO-FREQUENCY AMPLIFICATION OR THE MAGNIFICATION OF THE SOUNDS

ONE of the most important uses of the vacuum tube is to amplify or increase the intensity of electric currents. Tubes of certain design are specially adapted to this purpose. These tubes are called "amplifier tubes." They are sometimes referred to as "hard" tubes because of their high vacuum, as distinguished from the low-vacuum or "soft" tubes used as detectors. The single word "amplifier" generally refers to the combination of an amplifier tube and the necessary associated circuits to produce amplification. Such an amplifier is most readily understood if looked upon as a telephone repeater, that is, a device capable of receiving weak telephone currents and giving out other telephone currents of the same wave form but of greater magnitude. The increased energy in the output circuit is supplied by the plate or "B" battery. In this manner the voice or music currents are amplified or built up without distortion, at least in the ideal amplifier.

AUDIO-FREQUENCY AND RADIO-FREQUENCY
AMPLIFICATION

Already we have learned the difference between audio-frequency and radio-frequency amplification, but it may be well to point out this difference once more at this time.

Audio-frequency amplification has to do with the amplification of audio-frequency or audible current, such as that delivered by the detector in the usual receiving set. Radio frequency, on the other hand, has to do with high-frequency currents—those of frequencies above the audible range—such as the energy passed to the detector for conversion into audible currents. Radio-frequency amplification increases the sensitiveness of any given receiving set; it makes it reach out farther: but radio-frequency does not necessarily increase the sound volume obtained from that set. Audio-frequency, on the other hand, does not add much to the sensitiveness of the set; it does not mean much in reaching out farther: but it does build up the sound volume delivered by the set.

Therefore: *Radio-frequency* is used for *sensitiveness and distance*, and placed ahead of the detector; *audio-frequency* is used for *sound volume*, and is placed after the detector.

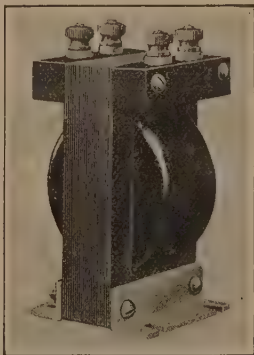
THE CONSTRUCTION OF AMPLIFYING TRANSFORMERS

The common method of amplifying is to use transformers for the purpose of transferring energy from one vacuum tube to the next. The efficiency with which this transfer is effected depends entirely upon the construction of the transformers used. Both radio-frequency and audio-frequency transformers have two electrical windings placed in close proximity

to each other. One winding is called the primary, which receives the energy from the first circuit, while the other is called the secondary, which delivers the energy created in it to another circuit. There is no electrical connection between the two windings; the relationship of the two circuits is a magnetic one.

In the usual radio-frequency transformer the same number of turns are used for the primary and secondary windings. In audio-frequency transformers, however, the secondary winding may contain from three to ten times as many turns as the primary, thus giving an amplifying ratio of from three to ten times. Audio-frequency transformers are rated $2\frac{1}{2}$ -to-1, 3-to-1, 5-to-1, 7-to-1, and so on, indicating the ratio between secondary and primary windings. The windings of the usual audio-frequency transformer are placed on a soft-iron core, which in turn is enclosed in an iron frame. Radio-frequency transformers, on the other hand, generally have the windings on a wooden spool or composition tube, without an iron core. That is why they are called air-core transformers.

The iron core of the audio-frequency transformer is made up of a large number of thin pieces of iron, or "laminations." These thin pieces of iron or laminations are insulated from one another by a coating of shellac or varnish, for the purpose of limiting the flow



Typical audio-frequency transformer, with two binding-post terminals for primary and two for secondary windings.

of stray currents known as eddy currents, which are induced in the iron as the result of the pulsating current in the primary winding. Some audio-frequency transformers have the iron core and windings exposed, while others are provided with an iron casing or shield and are known as the shielded type. This iron shield is not absolutely necessary; however, it does enable the builder to place the transformers closer together than is possible when using transformers of the non-shielded type, the magnetic fields of which are apt to interfere with one another when placed in close proximity.

The windings of the average audio-frequency transformer comprise thousands of turns of very fine insulated wire, usually enameled wire, while the average radio-frequency transformer has but some 25 to a few hundred turns.

HOW THE TRANSFORMER SERVES AS AN AMPLIFIER

The amplifying transformer, whether of the audio-frequency or radio-frequency type, is a coupling or link between one stage and another in the building up of signal strength or volume strength. The action of the amplifying transformer is based on changes in its magnetic field brought about by fluctuations in the current flowing through the primary winding. These magnetic fluctuations, in turn, cause currents with similar fluctuations to be induced in the secondary winding. The purpose of the iron core is to serve as an ideal path for the magnetic flux or field between the two windings. The iron core is constantly being magnetized and demagnetized and its magnetic polarity reversed many times per second in audio-frequency work. Audio-frequency variations range between 150 and 2,000 cycles, in the usual broadcast reception.

But when it comes to the handling of radio-frequency currents, calling for frequencies or changes of from 300,000 to millions of cycles per second, it is patently impossible to have an iron core, even if it is made up of small particles or laminations of iron, keep up with these fluctuations, hence the iron is dispensed with and an air core is substituted.

In amplification of the audio-frequency variety, we start with the output of the detector. If that output is not sufficient for our requirements, we lead it to the amplifier, which consists of an audio-transformer, amplifier tube, socket, rheostat, filament and "B" batteries, and the necessary wiring, as shown in the diagram on page 199. The output of the detector is led to the primary of the amplifying transformer, through which it flows for the purpose of setting up variations in the magnetic flux of the iron core. These variations of the magnetic flux set up currents in the secondary winding; and inasmuch as the transformer has many more turns of wire for the secondary than for the primary winding, the induced current is of higher voltage but of lower amperage than the energy introduced into the transformer. Thus if the secondary has five times as many turns as the primary, the voltage of the secondary will be five times that of the primary. However, the current, or amperage, flowing in the secondary, will be a fifth or less of that in the primary, as the total energy in the two windings must be about the same, with a slight deduction for electrical losses in the transformation. Hence it will be noted that if we increase the voltage in our transformer, we reduce the current or amperage in like ratio. However, the reason for stepping up the voltage and not the current in audio-frequency amplification is that the action of the amplifying tubes is based on the voltage existing between the grid and the plate.

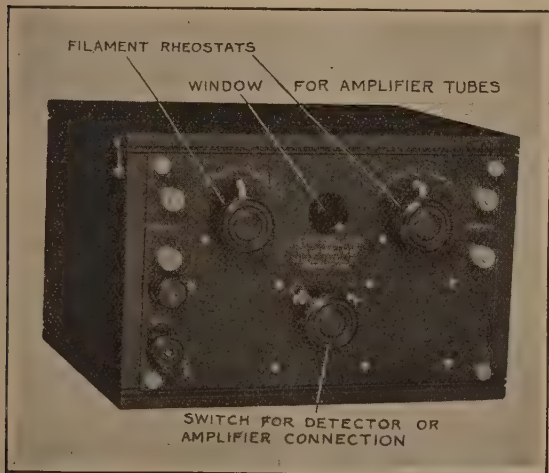
Thus with the higher voltage in the secondary winding of the transformer, we are in a position to get greater effects from the amplifier tube, to which this higher voltage is applied. One side of the secondary winding goes to the grid of the tube, while the other goes to one of the filament terminals. The plate of the amplifier tubes is connected with the positive pole of the "B" battery, the negative side of which goes to the filament. The filament is heated with an "A" battery. Of course, the usual practice is to have the same "A" and "B" batteries operate all the tubes of the set. The "B" battery is tapped off at $22\frac{1}{2}$ or 45 volts for the detector tube, while the amplifier tubes are run off the entire "B" battery.

Now the output of the amplifier can be led to another stage of amplification if desired, and the standard practice is to use two stages of audio-frequency amplification. Hence the plate circuit of the amplifier is led to the primary transformer winding of the next step, and again serves to induce an energy in the secondary winding several times greater in voltage. This increased energy is led to the grid and the filament of the next tube, and the amplifying process is repeated. If a third stage of amplification is desired, the same method is applied to the output of the second stage, although, for reasons dealt with further on, a third stage requires somewhat different handling.

THE QUESTION OF DISTORTION

If we could get along without amplification, we should have far better musical results from our radio sets. Unfortunately, however, the usual detector delivers only sufficient output for head-phone reception, and amplification must be resorted to for loud-speaker operation. Many receiving sets are provided with

jacks so that the operator can plug in head-phones just after the detector, without audio-frequency amplification. It is a revelation how much purer the music is when received without audio-frequency amplification. The usual neutrodyne receiver is quite handy in this respect, since it has jacks for plugging in after



Two-stage audio-frequency amplifier, with rheostat for controlling each tube separately, and with a change-over switch for eliminating the amplifier completely, for introducing one stage of amplification, and for introducing two stages of amplification.

the detector, first stage of audio, and second stage of audio. For long-distance reception the best results are generally obtained with head-phones plugged in after the detector, thus reducing distortion and ex-

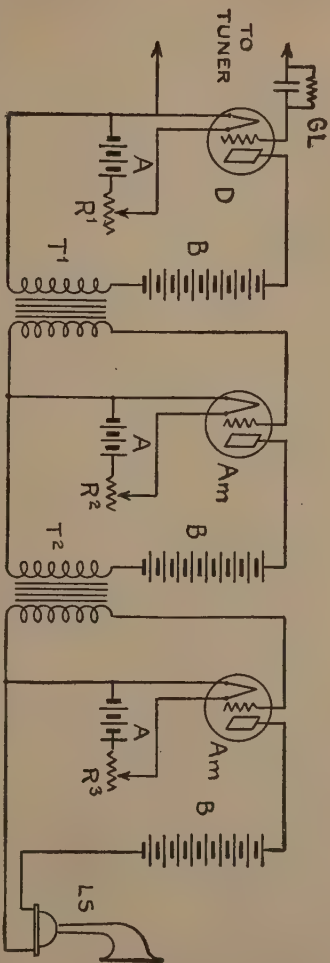
traneous noises to a minimum. The volume is, of course, much weaker than when using audio-frequency amplification, but the sounds are much purer and devoid of interference.

Distortion in audio-frequency amplification can be laid at the door of the transformer. Unfortunately, there is no way in which distortion can be entirely eliminated, although the better types of transformers have certainly reduced distortion to a minimum. Distortion is due to the failure of the transformer to amplify all frequencies to the same degree. Therefore, some sounds are amplified more than others, so that some notes are apt to shriek while others are entirely lost in the transformation. The reliable manufacturers furnish performance curves with their transformers, these curves indicating the amplification values at different frequencies. The best transformers are those whose curves are nearly flat, indicating that all frequencies within the usual musical range, from the bass saxophone to the high C of the soprano, will be amplified in about equal strength. One thing is certain, the general run of cheap transformers cannot be expected to render the musical results of the better class of transformers.

THE MATTER OF TRANSFORMER RATIOS

The matter of the ratio of the primary and the secondary windings has already been touched upon earlier in this chapter. It is a matter of some importance, although much more is made of it than is really necessary.

After all, the reliable transformer manufacturer is in the best position to advise the builder of an amplifier as to the proper ratios to use in connection with his transformers. Some radio authorities



This wiring diagram is intended to show the principle of audio-frequency amplification rather than the actual wiring of the usual amplifier. To simplify the presentation of the principle, separate "A" and "B" batteries are shown for each stage, although in practice a common "A" and a common "B" are used for the two stages as well as for the detector. In this diagram D is the detector tube. GL the grid leak and grid condenser, A the "A" battery. B the "B" battery, R the rheostats, T the transformers, Am the amplifier tubes, and LS the loud-speaker.

Schematic presentation of audio-frequency amplification, showing the arrangement of the detector tube and the amplifier tubes.

recommend a high ratio transformer, say 5-to-1 and even 7-to-1 for the first stage, inasmuch as the energy to be handled in the first step is not as large as that in the second step and therefore can be transferred more efficiently with the higher voltage. In such a case, the second step has a low-ratio transformer, say $3\frac{1}{2}$ -to-1, or 3-to-1, or even $2\frac{1}{2}$ -to-1, so that the chances of distortion are reduced to a minimum. Other radio authorities recommend the same low-ratio transformers for the two stages, such as $3\frac{1}{2}$ -to-1.

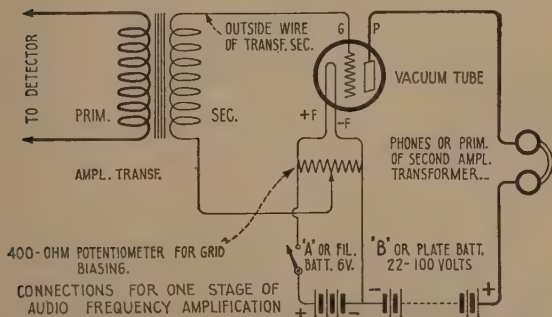
Another source of distortion lurks in the magnetic interplay of the transformers if they are placed too close to each other. Transformers which are not shielded should be placed at least four inches apart, and those with horizontal cores should be placed at right angles to one another so as to reduce the possibility of magnetic linkage. Some radio authorities recommend the shunting of the primary and secondary windings of the transformer with fixed condensers of small capacity such as .001 or .00025 mfd. Some of the finest toned radio sets have high resistance leaks across the secondary of the transformer. It is certain that such accessories make for sweeter musical results, although they are not absolutely necessary and, indeed, are rarely found in everyday practice.

PREVENTING DISTORTION WITH THE GRID BIAS

If the radio enthusiast is not satisfied with two stages of amplification and wishes to go on to a third stage, it is highly desirable to use what is known as a power tube, or a vacuum tube of greater capacity than the usual amplifier tube. The VT-2 is a power tube; so is the UV-202 or the C-202. Such tubes can be used with a very low ratio transformer, and they are capable of handling a large volume of energy with

200 to 350 volts on the plate. However, it now becomes necessary to use a "C" or grid biasing battery, since the grid has a tendency to become positively charged, which would paralyze its action.

Sometimes the second stage of amplification must be provided with grid biasing. The use of a negative grid potential in amplifier circuits is a very important factor in obtaining the greatest possible amplification without distortion and at minimum plate current.



One-stage audio-frequency amplifier with grid-biasing potentiometer for overcoming distortion when using high plate voltages.

Indeed, a "C" battery materially reduces the drain on the "B" battery, and is therefore incorporated in many receiving sets.

The necessary grid potential depends upon the type of tube and the condition under which it is used, and varies from zero to 9 volts negative. Tube manufacturers and transformer manufacturers usually specify the grid biasing potential. In order to obtain this

negative grid potential a "C" battery, comprising one or more small flashlight cells, is placed in the grid circuit at the point where the grid return is connected to the negative filament with its negative terminal on the grid side, as shown in the lower diagram on page 187.

Where lower plate voltages are used, sufficient biasing of the grid may be obtained by means of a potentiometer connected as shown in diagram on page 201. If a potentiometer is not used, then the inside of the transformer secondary should be connected directly to the negative side of the filament battery. It is also recommended that the lead from the outside of the amplifying transformer secondary to the grid of the tube be kept as short as possible and away from other wires, particularly those of the plate circuit. By so doing the tendency to howl will be greatly minimized.

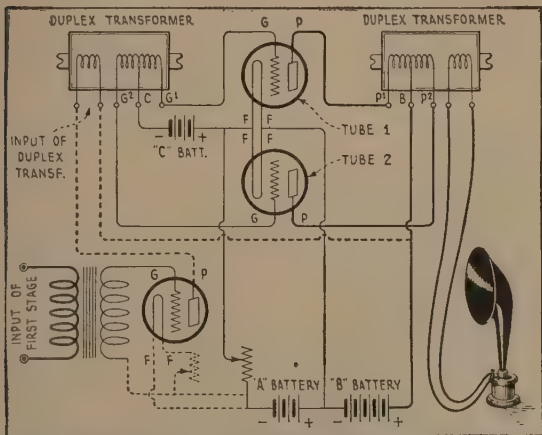
POWER AMPLIFIERS AND THE PUSH-PULL IDEA

When extremely loud results are required it becomes necessary to use the third stage of amplification already referred to, which is called the power amplifier. There are available on the market various types of power amplifiers, some of them especially intended for given types of loud-speakers so as to produce the best results.

Most radio authorities prefer the so-called push-and-pull type of amplifier for power amplification. This type calls for two tubes and two transformers for the third stage—by the way, if the set is receiving from nearby stations, the power amplifier may sometimes be operated directly from the detector, without the usual audio-frequency amplification.

In the usual amplifier, when the incoming signal is applied to the grid of the tubes, the increase and de-

crease of plate current are not equal because of the limited emission of the filament, but by the use of the special duplex transformers used for push-pull work, it becomes possible to have two tubes in the last stage of the amplifier, one tube tending to increase its plate current at the same time that the other tube is de-



Typical arrangement of a push-pull amplifier for efficient loud-speaker reception. The dotted lines indicate connections for first stage of plain audio amplification, while full lines indicate push-pull amplifier connections.

creasing its plate current. These effects can therefore be balanced and so avoid any distortion even on strong signals. The energy of the two tubes is then combined in the output transformer in such a way as to give the maximum volume of sound.

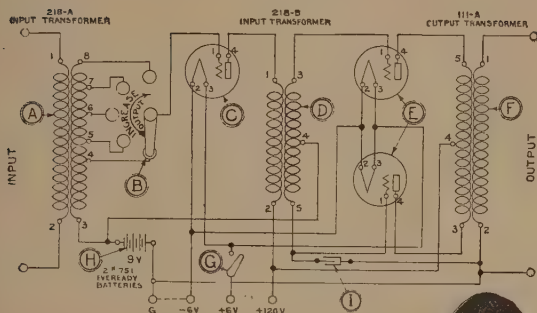
The input transformer is constructed with a low-loss

iron core, and has a single primary with two equal secondaries. The transformer is of medium ratio. The arrangement of the tubes and transformers, as well as the batteries and loud-speaker, is shown in the diagram on page 203.

THE RESISTANCE-COUPLED AMPLIFIER

There is another method of audio-frequency amplification regarding which little has been said, although if the present signs are correctly interpreted this method will soon be in quite common use. This method is the resistance-coupled amplifier, in which the usual amplifying transformer is replaced by suitable resistances and condensers for the transference of energy from one stage to the next. This method is preferable in several ways to the usual transformer-coupled amplifier. First of all, it is extremely simple to build; secondly, the components are surprisingly inexpensive; thirdly, the results obtained are remarkably pure and practically clear of distortion, as compared with even the best transformer-coupled amplification. The only disadvantage to this method is that the amplification factor is not as great as the transformer-coupled method, but nevertheless three stages of resistance-coupled amplification will prove equal in volume to two stages of transformer-coupled amplification, and far superior in the matter of musical quality.

Truth to tell, resistance-coupled amplification has not come into its own as yet because of the hang-over popularity of transformer-coupled amplification from the days prior to radio broadcasting. Transformer-coupled amplification was ideally suited to the amplification of dot-dash signals, because the transformers could be designed with a view to marked distortion or maximum amplification in the frequency range of



Wiring diagram of the push-pull power amplifier of the Western Electric loud-speaker outfit, and a photograph of the complete outfit as it appears in use.

the desired signals. Thus the radio telegraph receivers of those days generally made use of transformers with a maximum amplification in the neighborhood of 800 cycles, which was the average employed in dot-dash communication.

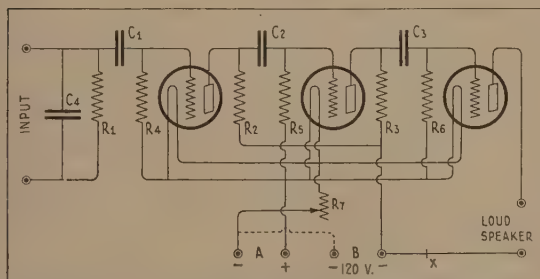
In the reception of radio broadcast programs, however, distortion is never desirable and, indeed, is quite undesirable and objectionable. Hence the importance of resistance-coupled amplification, which does not distort the signals. Contrary to a prevailing idea, resistance coupling does not involve high capacity isolating condensers and special resistances which are not available on the regular market, nor is the drain on the "B" battery excessive. Resistance coupling makes use of readily obtainable parts, which are low in cost; and the initial expense of three stages of this type of amplification is approximately the same as two stages of transformer-coupled amplification. Furthermore, the maintenance cost of resistance-coupled amplification is one-half that of transformer-coupled amplification. According to Zeh Bouck, well-known radio authority, when using 100,000-ohm coupling resistance and 120-volt plate potential, each amplifying tube when quiescent draws one milli-ampere, as compared with three to five milli-amperes dissipated in the average transformer stage.

Referring to the accompanying diagram of a resistance-coupled amplifier with three stages of amplification, it will be noted that C_1 , C_2 and C_3 are the so-called isolating condensers, but which in respect to location couple the various stages more truly than do the resistance. In fact, some authorities refer to such a system as "condenser-coupled" amplification. Mr. Bouck has found .006 mfd. condensers of sufficient capacity, while .0025 mfd. condensers give equally good results in a three-stage amplifier. The condensers are placed in the circuit to isolate the grids from the high

plate potentials and need only be of a capacity sufficiently high to by-pass the applied grid potential. C_4 is a by-pass condenser, nothing more; and .002 mfd. is an average and non-critical value for this member.

R_1 , R_2 and R_3 are the coupling resistances. Theoretically, the most efficient value of R is an infinitely high ohmage. This, however, is quite contrary to experimental findings, which recommend 100,000 ohms as the most desirable resistance with tubes available to the broadcast enthusiast.

R_4 , R_5 and R_6 are grid leaks, the respective values



Hook-up for a three-stage resistance-coupled audio-frequency amplifier, which produces exceptional loud-speaker results.

of which may be more or less arbitrarily fixed as 1 megohm, $\frac{1}{2}$ megohm, and $\frac{1}{10}$ megohm (1,000,000 ohms, 500,000 ohms and 100,000). These last resistances have no biasing effect, but function merely as leaks, draining the isolating condensers of superfluous charge and permitting the tube to return to its original operating point between audio-frequency impulses.

R_7 is a suitable rheostat for regulating the filament voltage of the three tubes. No separate rheostats are

required for each tube, in that the three tubes should be uniform.

The amplification effect is obtained in this type by the voltage drop through the resistance, which affects the grid charge of the next tube, and this grid charge in turn causes a marked effect in the plate circuit which is connected with the next tube through another resistance, causing a still more pronounced drop in voltage and another grid charge, and so on.

The resistance-coupled amplifier is connected to the output of the usual detector. However, in order to compensate for the drop across the resistance R_1 , the detector plate voltage is about doubled.

CHAPTER VII.

THE VOICE OF THE RADIO SET—TELEPHONE RECEIVERS AND LOUD-SPEAKERS

THE final link between the radio broadcaster and the radio audience is the device which translates the delicate electrical impulses of the receiving set into sound waves. How simple it is to ruin the entire radio broadcasting process from the microphone to the human ear, involving as it does an expensive studio with every provision for the finest acoustical results, elaborate speech amplifying systems, highly perfected radio transmitters, the best radio receiving set, the finest amplifying devices—and then a poor telephone head-set or miserable loud-speaker! Truth to tell, inferior loud-speakers, with their shrieks and squawks and horribly distorted musical rendition, have done much to create an unfavorable and unfair opinion of radio broadcasting. Happily, however, the public is soon converted to radio broadcasting when brought into contact with a good pair of head-phones or a good loud-speaker.

All of which carries the little moral that no matter what the receiving set may be, it is worth the best

available pair of head-phones or loud-speaker. Nothing else will do, if the radio enthusiast is at all interested in good results.

THE QUESTION OF TELEPHONE RECEIVERS

Radio telephone receivers are not just ordinary telephone receivers. They are far more sensitive than anything ever used in regular wire telephony. First of all, they are constructed with the utmost care; then they have windings of very fine wire, as compared with the relatively coarse wire used in the ordinary telephone receiver; again, the diaphragm of the usual radio receiver is much thinner and therefore more pliable and more delicate than that used in the ordinary telephone receiver; still further, in certain types of radio receivers the two receivers of a head-set are carefully matched in tone, so that both ears receive precisely the same sounds. This feature makes for the utmost response on the part of the ears, and therefore the best signals.

Quantity production has reduced the cost of radio head-sets to a point where everyone can afford to use the best. The cost of the best types is so low that there is hardly sufficiently difference to warrant the purchase of the poorer grades, especially in view of the difference in the receiving results brought about through the use of poorer grades.

After all, the better grade of radio head-set, with the standard telephone design consisting of a permanent magnet in the form of a ring or horseshoe, two bobbins or solenoids with thousands of turns of fine, insulated wire, and a thin diaphragm, will be found to give the best all-round results. There are special types on the market for which additional merits are claimed, but in actual practice these merits generally fail to

materialize, despite the additional cost of these special types.

One special type of head-phones makes use of a mica diaphragm that is actuated through a system of levers and an armature; in other words, the action of the usual solenoids is not brought to bear directly on the diaphragm as in the usual practice, but instead is caused to actuate an armature which in turn actuates the mica diaphragm through a system of amplifying levers. This type of receiver gives excellent results, but the construction is delicate and liable to damage through careless handling, as compared with the robust construction of the usual head-phones.

Another special type of head-phones has a single hobbin or solenoid which is said to provide a centralized pull on the diaphragm, instead of the usual double-pole arrangement. So far as all-round efficiency is concerned, this design fails to show any advantage over the usual bi-polar design; indeed, it is not as efficient, if anything. The main advantage of this design appears to be in a more economical construction, which should be reflected in lower cost.

After all is said and done, the standard design of receiver will be found quite satisfactory in every way.

GRADUATING TO THE HORN

Sooner or later, and the sooner the better, the radio enthusiast graduates to the horn reproducer. That is to say, he discards the head-phones in favor of some form of horn reproducer which fills a room with the radio entertainment. Thus he gets away from the harness of the head-phones, and he provides unselfish entertainment for the family and friends. Instead of one or two or three persons listening to a radio program, the horn reproducer enables a dozen or more persons

to listen with absolute comfort, just as they would listen to a conversation or a phonograph or a piano. In truth, there is really no comparison between the head-phones and the horn reproducer in the matter of radio entertainment. When it comes to long-distance reception, however, there is still a definite application for the head-phones. Also, where low first cost and operating expenses are primary considerations, head-phones must be employed. But for all-round radio entertainment the horn reproducer is quite essential.

Now, let us be frank about the horn reproducer. It takes considerable power to produce sound waves. The usual telephone receiver has a thin diaphragm which is actuated by the delicate currents flowing through the windings or solenoids; and the vibrating diaphragm, in turn, applies varying pressure on the air which comes in contact with it, thus setting up vibrations in that air which pass on to the human ear drum, setting the latter in motion and producing the sensation of sound. In the usual telephone receiver the diaphragm moves but an infinitesimal distance and therefore produces very delicate variations in the air. The sound waves, accordingly, are quite weak. However, inasmuch as the telephone receiver is held close to the ear, the weak sound waves have but a short distance to travel to the human ear drum. Furthermore, no sound waves are dissipated. Hence loud signals are heard with head-phones.

When it comes to filling a room with sound, on the other hand, the problem becomes more difficult. The weak fluctuations or flexing of the telephone diaphragm are no longer sufficient to set up the necessary volume of sound waves. Such waves as are set up have to move through a large space; they are no longer confined to a definite path direct to the human ear drum. It so happens that much of the sound energy

is dissipated, and only a small portion reaches the human ear drum, usually too little to be audible.

It takes powerful vibrations or flexing of the telephone diaphragm to set up sound waves that may be detected at some distance away. The ordinary telephone head-set, when operated from a single-tube receiver, will produce weak signals which may be heard only when the head-set is worn. With a one-stage audio amplifier, the signals are quite loud when the head-set is worn. With a two-stage audio amplifier the signals are often so loud that the head-set may be laid on a table and the signals heard throughout a room, without a horn.

THE TABLE-TALKER—A STEPPING STONE TO THE LOUD-SPEAKER

Only when a radio set is capable of producing such loud signals as last mentioned is the horn reproducer feasible. If the signals cannot be heard when the headphones are laid on the table, then a horn reproducer is out of the question. Contrary to the prevalent idea, a horn does not amplify the signals; it merely concentrates, and directs the sound waves so as to make the best use of them. Unless the diaphragm of the telephone receiver has sufficient power to produce powerful sound waves, a horn is of little or no use.

There are several types of horns which may be used in conjunction with the standard head-phones. Some types take the head-phones, just as they are, and hold them at the small end of a horn, thus gathering the sound waves and projecting them to the best advantage. Other types take a single telephone receiver and clamp it on the small end of the horn.

Aside from these horn attachments, there are the so-called table-talkers, consisting of a standard type

telephone receiver permanently fastened to a horn especially designed for it. Table-talkers will give excellent results on small two-tube and three-tube receiving sets, filling a small room with the radio entertainment. However, the table-talkers, costing anywhere from \$5.00 to \$15.00, should not be expected to take the place of the loud-speakers, which cost anywhere from \$20 to \$50 and up.

WHEN THE PHONOGRAPH HANDLES RADIO PROGRAMS

If the radio enthusiast has a phonograph at hand, he can readily solve the horn reproducer problem by using one of the several excellent phonograph attachments now available. The scheme in this case is to use either the standard head-phones, which are applied to the



Typical table-talker, which is virtually an ordinary telephone receiver equipped with a horn.

phonograph in place of the usual phonograph reproducer, or a special phonograph unit which goes on the tone-arm in place of the phonograph reproducer. Using two stages of audio-frequency amplification in connection with any good radio receiver, it is possible to operate a phonograph unit so that it will fill a large room with radio entertainment. The author has been using the Westinghouse phonograph unit and the DeForest phonograph unit with excellent results. Indeed, the results compare favorably with the general run of loud-speak-

ers, which cost several times as much. The usual phonograph has an excellent horn which is fully as large if not larger than the horn supplied with most loud-speakers, hence there is no reason why a phonograph should not give excellent results.

Several leading phonograph manufacturers are now turning out combination machines for phonographic and radio entertainment. The standard practice is to include a standard make of radio receiver in the phonograph cabinet, connected with a phonograph unit which may be attached to the tone arm in place of the usual reproducer. This arrangement calls for a minimum of change in the standard phonograph design, yet gives the results desired by the average public.



Semi-dynamic type of loud-speaker, in which mechanical amplification is used.

LOUD-SPEAKERS OF ALL KINDS

The eventual stage in radio entertainment is the loud-speaker, which provides loud, clear, pleasing radio music and talks for any number of listeners. The loud-speaker requires considerable power to operate, as compared with head-phones, table-talkers and most of the phonograph units; but the results obtained are well worth the additional expense involved.

Of loud-speakers, there are many types. For the

purpose of convenience it is feasible to divide loud-speakers into three broad classes: First, loud-speakers of the plain electro-magnetic type, which are merely a modified standard telephone receiver and operate on the output of the usual two-stage audio amplifier; the electro-mechanical type, in which the pull of the solenoids is not applied directly to the diaphragm but instead is applied to an armature, which in turn transmits the power through a series of levers to the diaphragm, with a mechanical amplifying action; and the

electro-dynamic type, with its powerful magnetic field in which is placed a movable coil through which flows the audible current.



Phonograph attachment in use, for converting the standard phonograph into an excellent loud-speaker. This attachment takes the place of the usual reproducer.

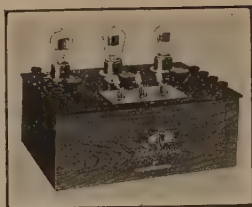
The plain electro-magnetic type of loud-speaker is by far the most common today. It is practically an out-growth of the table-talker, with a more powerful telephone unit and usually some means of varying the air-gap between the pole pieces and the diaphragm. The ability

to vary the air-gap is highly desirable, since with powerful signals the air-gap must be increased so that the diaphragm, now greatly flexed, will not strike the pole pieces and cause a hum or chatter, while with weak signals the air-gap must be reduced to a

minimum so as to conserve the weak magnetic variations.

Truth to tell, remarkable strides have been made with the plain electro-magnetic type of loud-speaker. This simple type has been developed far beyond the original expectations, and it is therefore not surprising to find it so widely used at present. With the powerful output of the amplifiers now built into the regular run of receiving sets, the plain electro-magnetic type of loud-speaker receives ample energy to ensure a proper sound volume, despite the absence of any amplification in the loud-speaker itself.

The electro-mechanical type of loud-speaker makes use of mechanical amplification. To this end, the electro-magnets or solenoids actuate an armature, which in turn operates the diaphragm through a system of amplifying levers. The diaphragm may be of mica or some other material in place of the iron diaphragm of the plain electro-magnetic type, thus making for better acoustical properties. The electro-mechanical type of loud-speaker is often supplied with an adjustment device for regulating the distance between the armature and the electro-magnet poles, so as to make for the utmost efficiency with any given strength of radio signals.



Three-stage power amplifier for use with powerful loud-speaker.



Single-stage power amplifier unit of compact design.

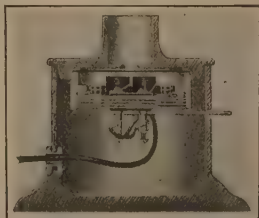
THE ELECTRO-DYNAMIC LOUD-SPEAKER



Electro-magnetic type
of loud-speaker.

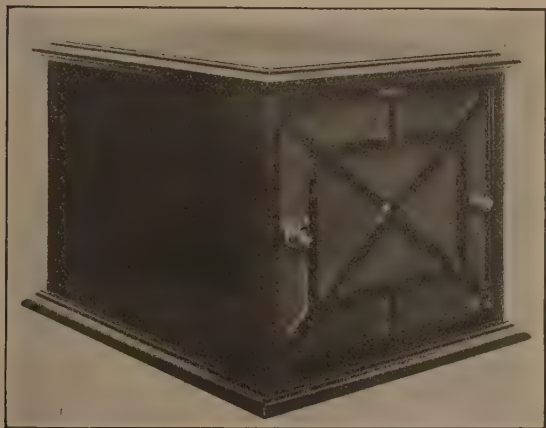
Finally, we come to the electro-dynamic principle, which makes use of a powerful magnet with a small air-gap in which is placed a very small coil of fine wire attached to a diaphragm but not touching the poles of the powerful magnet. This little coil is connected to the radio set or amplifier, and the fluctuations due to the voice waves pass through it. The fluctuations pass only when someone is talking or when there is music, since that is the only time fluctuations are present. At all other time there is no current at all passing through this little coil. When talking or music begins, the fluctuations produced in the receiver circuits

pass through this little coil, and as they do so the little coil is very strongly forced out or drawn into the powerful magnetic field in the air-gap. It is forced in and out in exact accordance with the fluctuations of current which pass through it and, as it is rigidly attached to the diaphragm, the diaphragm



Mechanism of loud-speaker
shown above. Note adjust-
ment lever.

has to follow its motion. Thus the diaphragm sets up air vibrations and reproduces perfectly the speech or music which was presented at the microphone end of the broadcasting system. Due to the intense magnetic field in the air gap, the little coil is able to develop great power in its motion and can move a very large diaphragm, which in turn causes a large disturbance of



Cabinet type loud-speaker, with concealed horn and mechanism as well as the power amplifier. This type is bound to come more and more into favor, displacing the exposed horn types of loud-speakers.

air in the horn. Hence loud signals from the horn. Indeed, this type of loud-speaker will emit sound in exact proportion to the amount of fluctuating current supplied to it.

The drawing on page 221 shows a sectional view of the electro-dynamic loud-speaker, which is known as the Magnavox. It will be noted that 1 is the socket into which the horn is fitted. 2 is a metal cover protecting the sound chamber and diaphragm assembly, while 3 is the large and scientifically constructed sound chamber. 4 indicates the leads from the movable coil to the step-down coil. 5 is the non-magnetic diaphragm. 6 is the hanger connecting the movable coil to the diaphragm. 7 is the top plate representing one pole of the electro-magnet. 8 is the air-gap in



The electro-dynamic type of loud-speaker with volume control and step-down coil.

which the movable coil floats and which becomes a strong magnetic field when current flows through the field winding 10. 9 is the "movable coil" wound with fine copper wire through which flows current from the receiving set or amplifier. 10 is the electro-magnet through which current flows from the filament battery, strongly magnetizing the pole pieces 7 and 11. 11 is an iron core, not a permanent magnet, to form the center pole of the electro-magnet.

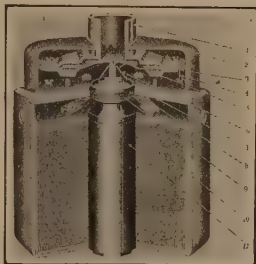
The standard Magnavox loud-speaker, which represents the electro-dynamic principle of sound reproduction, requires a field excitation current in addition

to the output from the receiver or amplifier. That is to say, the magnetic field of the Magnavox must be energized by a six-volt current from a storage battery or from four dry cells. The current draw is about .7 ampere in the Type R Magnavox, hence may be taken from the storage battery that supplies the filaments of the tubes. A variable

resistance placed in the electro-magnetic field winding circuit and known as a volume modulator, permits of varying the strength of the sound output in a most delicate manner, so as to obtain any desired degree of sound.

The Magnavox loud-speaker is also available in the semi-dynamic design, with which no external battery is required. This design is especially intended for use with dry-cell tubes, and provides a maximum of sound volume from the limited output of such tubes. In this semi-dynamic design of Magnavox the powerful electro-magnetic field is replaced by a permanent magnetic field, while the movable coil in the magnetic field is retained.

The author has had considerable experience with the Magnavox loud-speakers, both of the Type R-3 or electro-dynamic design, with volume modulator, and the Type M or semi-dynamic design. It is but fair to state here that these Magnavox loud-speakers not only deliver a surprising sound volume from a given receiving set output, but the tonal quality is exceptional.



Mechanism of electro-dynamic loud-speaker shown on facing page.

POWER AMPLIFIER EQUIPMENT

All loud-speakers of the larger types require power amplification for the proper results. Hence the makers of such loud-speakers generally provide suitable power amplifier units which may be used in conjunction with standard receiving sets. For nearby broadcasting stations, the power amplifier unit can sometimes be connected directly with the detector of the receiving set, while for weaker signals it becomes necessary to use one or two stages of regular audio-frequency amplification before the power amplifier.

In several offerings the power amplifier unit is made an integral part of the loud-speaker. In one instance the power amplifier is mounted in the base of the loud-speaker, while in another the power amplifier is placed in the attractive cabinet which houses the loud-speaker horn.

There is no doubt but that the loud-speaker horn must eventually be concealed. We are now passing through a stage in radio development comparable with that in phonograph history when no phonograph was complete without a huge brass horn or morning-glory horn projecting out from the machine. Already, several loud-speaker manufacturers are placing their horns in attractive cabinets, so as to have them blend with the atmosphere of the usual living room. Many receiving sets of the furniture type have concealed horns. More and more the concealed horn must come into use, as the radio receiving set is accepted into the home as a permanent thing rather than a passing fancy.

CHAPTER VIII.

RADIO-FREQUENCY AMPLIFICATION, OR STRETCHING THE LONG ARM OF RADIO

RADIO-FREQUENCY amplification is steadily gaining in favor. Not so long ago it was considered as a laboratory experiment, capable of producing remarkable results if properly handled, but rather too tricky for everyday use. Today we find radio-frequency amplification widely used in both the manufactured receivers and the home-made receivers. No longer is there any mystery or uncertainty about radio-frequency amplification.

The difference between radio-frequency and audio-frequency amplification has already been dealt with in this work. Audio-frequency amplification is the more important of the two and is in far more common use. Indeed, every two- and three-tube receiver, with but rare exceptions, has one or two stages of audio-frequency amplification. Audio-frequency increases the sensitiveness of the receiver by building up the sound volume. One can readily add two or three stages of audio-frequency amplification after the usual detector, but these stages of amplification are certain to be noisy

and to introduce some very undesirable distortion in the loud-speaker or head-phone results. It is better to amplify the signals before they get to the detector, since such amplification does not introduce extraneous noises, nor does it make for distortion. And that is precisely where radio-frequency amplification comes into its own.

THE MATHEMATICS OF RADIO FREQUENCY VS. AUDIO FREQUENCY

On the basis of the sound output, the radio-frequency form of amplification sells itself to the radio enthusiast. Supposing for a moment that our radio and audio amplifiers are going to work equally well and that they have an amplification constant of eight, counting both the transformer and the tube. In the accompanying Fig. A, if we supply 2 microvolts to the radio-frequency amplifier, we will get out of it 2 times 8 or 16 microvolts. When we supply these 16 microvolts to the detector we will get from it a response proportional to 16 times 16 or 256. It will be noticed that the effect is as if the detector squares the input voltage.

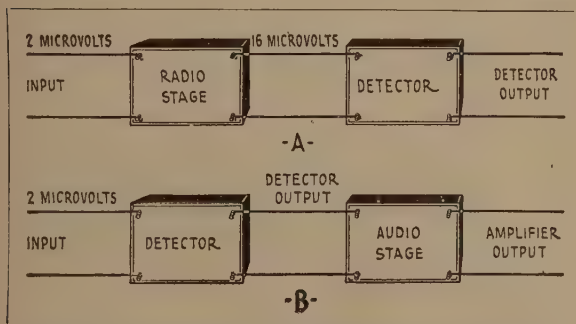
Now in Fig. B if we supply the same 2 microvolts to the detector direct, we will get out of it a response proportional to 2 times 2 or 4 microvolts. When this is supplied to the audio-frequency amplifier, it will be multiplied by 8 as before and we will get the effect of 32 microvolts out of this combination. It will be noticed that this is very much less than was secured in the case of the radio-frequency amplifier.

In practice, so states Mr. S. Kruse, Technical Editor of *Q S T*, to whom the author is indebted for these few facts regarding amplifiers, the effect is not quite as good as this because a stage of audio-frequency amplification

gives considerably more amplification than a stage of radio-frequency amplification, if both are run well below the oscillating point. The ideal arrangement, of course, is to employ both radio-frequency and audio-frequency amplification.

THE OPERATION OF THE DETECTOR TUBE

At this point it is well to say a few words regarding the operation of a vacuum tube as a detector, in order



Why radio is preferable to audio frequency. These diagrams indicate arrangement for both kinds of amplification with regard to detector. In the arrangement shown at A, the detector output is proportional to 16 times 16 or 256. In B the amplifier output is proportional to 4 x 8 or 32.

to understand how such a function fits in with the radio-frequency amplification scheme. When a tube is operating as a detector, it is provided with a grid condenser in series with the grid lead, as well as with a grid leak. When a signal is received the grid condenser is charged by the alternating or oscillating current that is impressed on the condenser. The con-

denser discharges its charge upon the grid of the tube. When the current impressed on the grid of the tube is positive, the electronic flow between filament and plate is increased, but when the current impressed on the grid is negative, the electronic flow is decreased to such a degree that there is no noticeable change in the plate current and therefore no signal is heard in the headphones or loud-speaker.

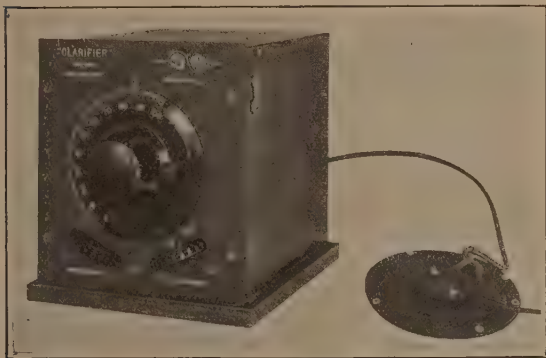
It is this action of the tube that rectifies the radio waves intercepted by the set and causes audible signals. The audible signals are a replica of the sounds impressed on the waves at the broadcasting end, or represent the spark frequency of the spark transmitter when listening to dot-dash messages.

In radio-frequency amplification the amplifier is placed ahead of the detector tube. The radio-frequency amplifier then takes the signal that enters the tuning members of the set and amplifies them by means of the transformers and the tubes until they have reached the desired strength to be passed on to the detector for rectification into audio-frequency current.

THE TUNED AND THE FIXED TRANSFORMER VARIETIES OF RADIO-FREQUENCY AMPLIFICATION

There are two ways in which radio-frequency amplification is accomplished: First, the tuned radio-frequency method, in which the various stages of amplification must be tuned, thus calling for a multiplicity of controls in addition to those of the usual tuning members; secondly, the fixed transformer method, in which the successive stages of radio-frequency amplification are coupled together by means of fixed-winding transformers, in a manner not unlike that employed in audio-frequency amplification, and one that does not require additional controls. Each method has its ad-

vantages and disadvantages. Thus the tuned radio-frequency method is considerably more efficient on the low wave lengths employed in broadcasting than the transformer method. But on the other hand, it involves an additional control for each radio-frequency stage, and this complicates the operation of a receiver by that much; whereas the trend of today is towards fewer and simpler controls. The transformer method, on the other hand, is not so efficient but requires no



Radio-frequency amplifier unit which is used in connection with any existing receiving set. It is connected to the antenna and ground, and its output coil is placed near the vario-coupler or inductance coil of the receiving set. This unit prevents radiation while increasing efficiency of receiver.

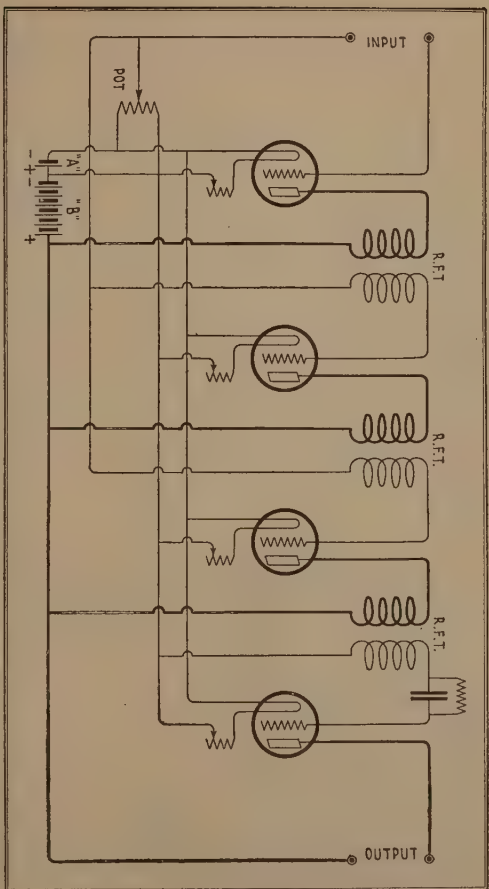
additional controls. Its operation is quite as simple as that of the usual audio-frequency amplifier, except that a potentiometer adjustment is sometimes required for the best results.

Fixed-winding transformers for radio-frequency am-

plication are available in many different styles, but the basic idea is always the same. Such a transformer consists of two windings placed close together, so as to permit of the transfer of energy from one to the other. Generally no iron core is used, because of the high-frequency nature of the currents in such transformers, as already explained earlier in this work. Instead, the connecting medium between the windings is simply air, and they are therefore said to be of the air-core type.

Radio-frequency transformers of the fixed-winding type are made to operate at a fairly high efficiency over a moderate range of wave lengths, although, truth to tell, they operate at their highest efficiency at a very definite wave length. The usual run of radio-frequency transformers of the fixed-winding type are designed for reasonable efficiency over a wave length range of 200 to 600 meters, which takes in all the broadcasting wave lengths.

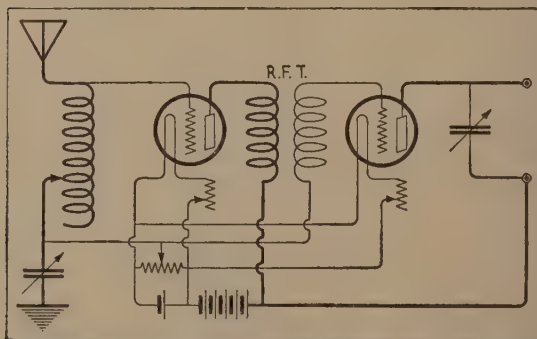
The accompanying diagram shows the general idea of radio-frequency amplification, using fixed-winding transformers. It will be noted that the transformers are used in the same manner as the usual audio-frequency transformers in coupling one tube to the next tube. The only difference is in the potentiometer, which is connected across the "A" battery and has a movable contact arm connected to the filament side of the secondary circuit. The purpose of the potentiometer in radio-frequency amplifiers is to stabilize the circuits; that is to say, the capacity of the tubes in a radio-frequency amplifier causes a feed-back of energy from the plate to the grid, and this gives rise to tube oscillations. When a tube breaks into oscillation, it no longer amplifies properly. Hence some means must be employed to stop these troublesome oscillations. The simplest means is the potentiometer, which places the grids of the tubes under a slight positive bias. By



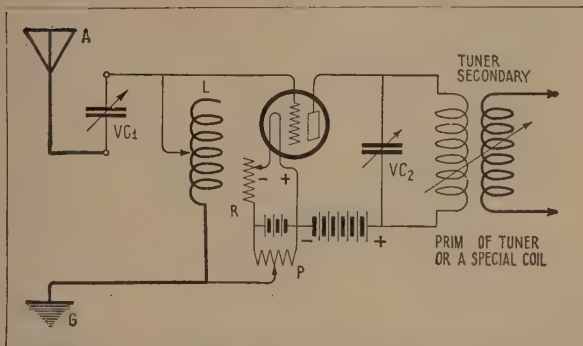
Three-stage radio-frequency amplifier unit, using fixed transformers. The first three tubes are the amplifiers, while the fourth tube is the detector. This arrangement is typical of fixed transformer coupled radio frequency, using a potentiometer to prevent oscillations.

swinging the arm of the potentiometer the grid can be made negative or positive according to where the arm is placed on the winding. The tube will not oscillate unless the grid is fully negative.

The next diagram shows another interesting application of the fixed transformer radio-frequency amplifier to any two-circuit or three-circuit set so as to increase its range. In this instance there is only one radio-frequency transformer, but two tubes are employed. The reason is that the primary and the secondary of the usual two-circuit or three-circuit tuner serve as the second radio-frequency transformer. A variable condenser is placed across the primary, while the secondary is tuned in the usual manner, making this arrangement one stage of fixed radio-frequency and one stage of tuned radio-frequency amplification. Because of the tuning of the second stage, this arrangement is



Ingenious radio-frequency amplifier that may be used with the existing receiver. This arrangement has one stage of fixed transformer coupled amplification, and one of tuned radio frequency, using the vario-coupler of the set as the tuned radio-frequency transformer.



Another radio-frequency amplifier that may be used with existing receiver. The values for the various members must necessarily vary according to circumstances. However, VC-1 may be a 23-plate variable condenser; L a 100-turn inductance coil; P a 400-ohm potentiometer; R a rheostat; VC-2 a 23-plate variable condenser, connected directly with the usual vario-coupler of receiver.

highly selective and therefore quite troublesome to operate, but it will be found to be efficient.

When it comes to adding this arrangement to a single-circuit tuner, it is necessary first of all to change the tuner into a double-circuit set without regeneration, or else obtain a variometer and place it in the plate circuit of the remodeled tuner.

THE VERSATILE TUNED RADIO-FREQUENCY AMPLIFIER

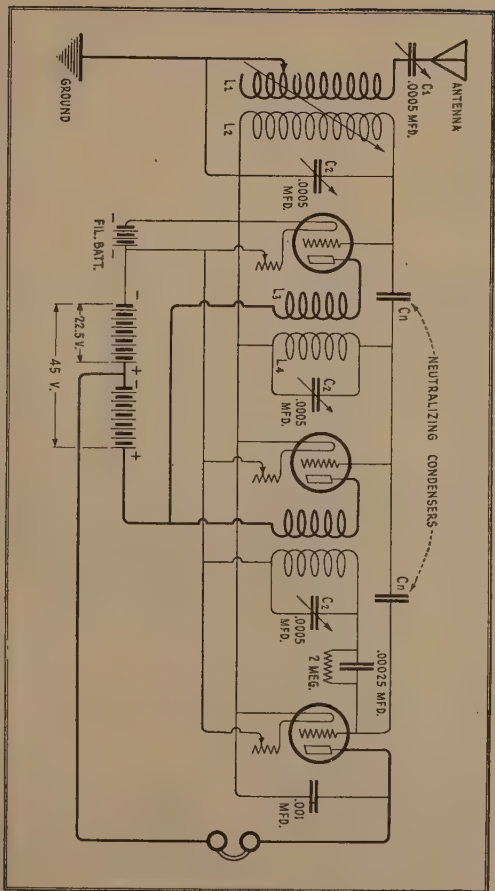
While the transformer type radio-frequency amplifier is more or less standardized, such is not the case with the tuned radio-frequency method. There are many different ways in which tuned radio-frequency amplification may be achieved, and many of these different ways are in present-day use.

The diagram shown above illustrates a typical

method of tuned radio-frequency amplification. This scheme happens to be that of a compact outfit which may be used in connection with any existing receiver, for adding radio-frequency amplification. It is of the tuned coupled circuit type, and has a tuned grid circuit using a variable condenser and an inductance, with the inductance switch so arranged that either a loop or an antenna may be employed. The plate circuit is tuned by means of another variable condenser and an output inductance which may be either the primary of the vario-coupler of the usual loose-coupled tuner, or a special inductance coil supplied with the amplifier, which may be placed in any location where it is in inductive relation to the detector circuit of the usual tuner, of whatever type. The first method, of using the primary of the two-circuit vario-coupler as the output inductance, may be used on any standard tuner in which this primary circuit is not grounded to the filament.

A tuned radio-frequency amplifier may be arranged with two compact inductance coils, suitably mounted so that their coupling may be varied. The variation of the coupling makes the use of tuning condensers across the secondary unnecessary, although sharper tuning and more efficient results are obtained with a secondary condenser.

One of the most popular types of tuned radio-frequency devices is the condenser-tuned transformer, such as is used in the well-known neutrodyne receivers. The primary and secondary windings of such a transformer are fixed, with an air core between; but a variable condenser is connected across the secondary winding to tune it into resonance with the primary. In the neutrodyne circuit, which is an ingenious form of radio-frequency amplifier with detector, the essential feature is the use of so-called neutralizing condensers, connected between the grids of successive



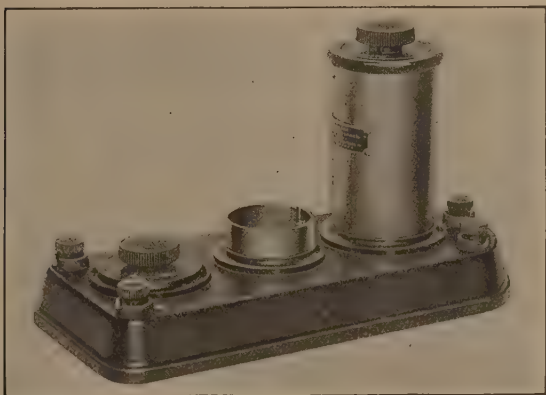
Tuned radio-frequency amplifier circuit with detector tube and with neutralizing condensers connecting the grids of all the tubes, so as to eliminate the possibility of oscillations. This is essentially the principle of the neutrodyne circuit, which is one of the most practical radio-frequency receiving circuits in present-day use.

tubes. These neutralizing condensers serve to counteract or neutralize the regenerative effect of the capacity coupling between the grid and the plate of the vacuum tubes. If these condensers are properly adjusted, the voltage impressed on the grid of the second tube through the capacity of the first tube is balanced against the voltage reaching the second grid through one of the neutralizing condensers, thus stopping the self-oscillations that would otherwise take place. Further on in this work we shall deal at length with the popular neutrodyne circuit, but suffice it to make passing mention of the fact that it is essentially a radio-frequency amplifier with maximum efficiency.

Then there is the vario-transformer, which is a new instrument designed as a coupling device to link the tubes in a radio-frequency amplifier. It is a radio-frequency amplifier transformer so constructed that the inductances of the primary and secondary coils and the mutual inductance between them are continuously and simultaneously variable over a wide range. The advantages of such a variable transformer principle have long been appreciated, for this arrangement permits the operator to tune his radio-frequency amplifier to the wave length of the station he desires to receive. Such tuning materially increases the sensitiveness and range of the receiver, enabling distant stations to be heard on a small antenna or loop, increasing the volume of the speech or music received from all stations, besides greatly assisting in the exclusion of undesired stations.

The vario-transformer is the invention of Stuart Ballantine, a well-known radio experimenter and author. The present highly developed instrument is designed particularly for broadcast reception, and has a range of adjustment for maximum amplification of from 200 to 600 meters. Its electrical characteristics have been adjusted to give maximum amplification with the UV-

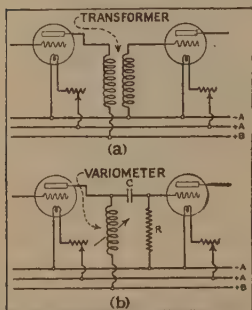
199 or C-299, UV-201-A or C-301-A, and the WD-11 and WD-12 or C-11 and C-12 tubes. It affords such opportunity for fine adjustment without instability that a single stage with detector furnishes non-regenerative amplification for loud, clear signals in telephone receivers, when used with an antenna of reasonable dimensions. The mechanical construction makes



Radio-frequency amplifier unit making use of the Ballantine vario-transformer. This unit may be used in connection with any receiving set to increase its sensitiveness and range. A typical arrangement is shown on page 237.

for extreme compactness. An adjusting knob and dial are provided for purposes of tuning. The Ballantine vario-transformer can be mounted either upon the small base in a vertical or horizontal position, or upon a panel using the panel mounting collar. Either of these mountings is furnished with the instrument.

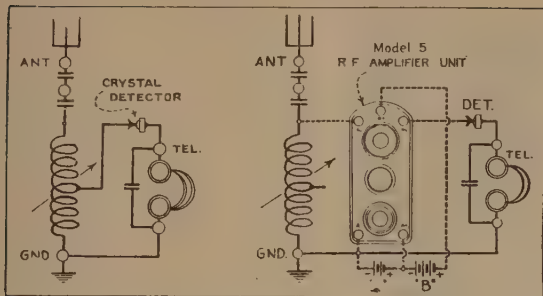
In the illustration on page 235 is depicted the Ballantine vario-transformer arranged in a radio-frequency amplifier unit, containing all the auxiliary apparatus. With the addition of a vacuum tube, this unit is complete and ready to function. This unit will be found especially convenient for those who wish to assemble their own receivers with a minimum of trouble and mechanical labor, and also for those who have a crystal receiving set or a plain vacuum tube detector set which they wish to improve by the addition of radio-frequency amplification. Indeed, this unit, when added to an ordinary crystal receiving set, gives results that are little short of astounding. The quality of the tone produced by most crystals, particularly those of the ferro-silicon class, is very much superior to that which results from detection with a vacuum tube. The inherent limitations of the crystal detector, with a receiving range of from 15 to 25 miles



Two methods of radio frequency amplification. transformer coupled: variometer coupled.

under average conditions, are removed by the addition of the radio-frequency amplifier unit, which increases the receiving range until it compares favorably with a vacuum tube detector. Hence distance combined with crystal-clear reception is brought about.

The manufacturers of the Ballantine vario-transformer and amplifying unit have prepared attractive literature which furnishes the specific details for the employment of these devices,



How the Ballantine vario-transformer amplifying unit shown on page 235 may be connected with an ordinary crystal type receiving set. This diagram shows the crystal receiver in its original form, and with the amplifying unit.

hence our rather limited space need not be taken up for this subject.

THE PHUSIFORMERS IN RADIO-FREQUENCY AMPLIFICATION

Another form of radio-frequency amplifying transformer is the phusiformer, which has a primary and secondary winding with adjustable coupling. The phusiformer is a neat instrument and lends itself to ready assembly into a complete receiving set. It is provided with a dial, and it is tuned in the same general manner as a neutrodyne receiver; that is to say, the readings for the dials are logged or charted, and the receiver is tuned by setting the dial readings at the same points each time for a given station. As in the neutrodyne receiver, the same kind of dial is used for the antenna-ground circuit, so that with a phusiformer receiver with two-stages of radio-frequency amplifica-



Typical phusiformer unit with control handle and dial.

tion, three phusiformers and three similar dials are employed.

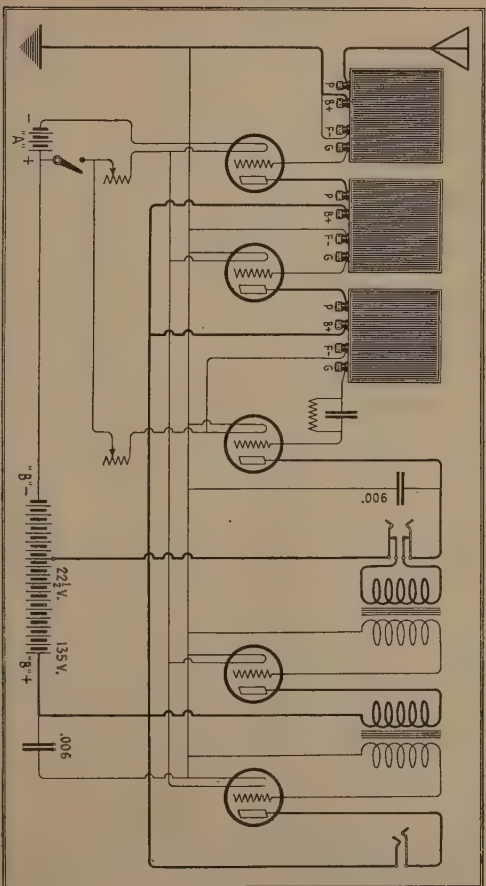
The diagram on facing page shows how the phusiformers are arranged in a five-tube receiver. It will be noted that the filament terminal of the last phusiformer is connected to the positive side of the filament when a UV-201-A or a C-301-A tube is used for the detector. To prevent coupling between phusiformers, they should be separated $6\frac{1}{2}$ inches between centers.

Otherwise, the diagram is self-explanatory.

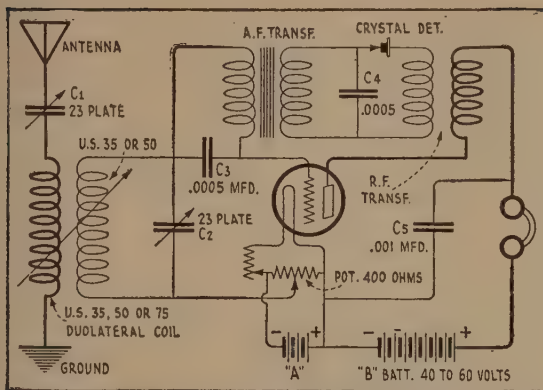
On page 240 is shown how the phusiformers are wired to provide radio-frequency amplification for an existing receiving set. Here the phusiformers are depicted in symbol form, with the primary and secondary windings indicated. It will be noted that the terminal on the third or last phusiformer marked "Grid" is connected with the tuning element side of the grid condenser in the existing receiver. Where common "A" and "B" batteries are employed for the operation of both the phusiformer amplifier and the existing receiver, it is unnecessary to wire from the terminal marked "filament" on the amplifier to the detector and audio-frequency amplifier. In the case of existing receivers in which a by-pass condenser is not provided in the detector plate circuit, it is advisable to connect a .006 microfarad condenser



Fixed radio-frequency transformer intended for the usual broadcasting wave length band signals.



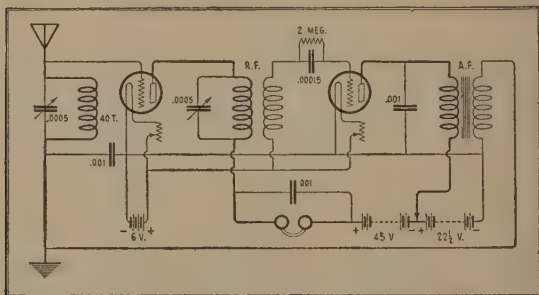
Connections for three phusiformers arranged for a complete receiving set. The first two tubes are amplifiers, the third tube is the detector, and the last two tubes the audio-frequency amplifiers. Note the jacks indicated in this sketch, for plugging in head-phones or loud-speaker after detector and after audio-frequency amplifier.



Typical single-tube reflex receiver, using a crystal detector. The values for the various components are indicated. This set is the equivalent of a two-tube regenerative receiver, and is simpler to operate.

The reflex idea may be applied in a wide variety of ways, ranging from a single tube and a crystal detector, to three or four tubes and even more, which are used for the double amplification. The simplest reflex set is one consisting of a single amplifier tube and a crystal detector, arranged as shown in the accompanying diagram which is typical of this combination. In this arrangement the incoming signals are first amplified at radio frequency in the usual manner, using a fixed winding transformer. They are then detected by a crystal detector, although a vacuum tube can be used for this purpose if preferred. The crystal, with its silent operation, is usually preferred. The rectified signals, now in the form of audio-frequency current, are returned to the first tube and amplified at audio-frequency, passing on to the audio-frequency trans-

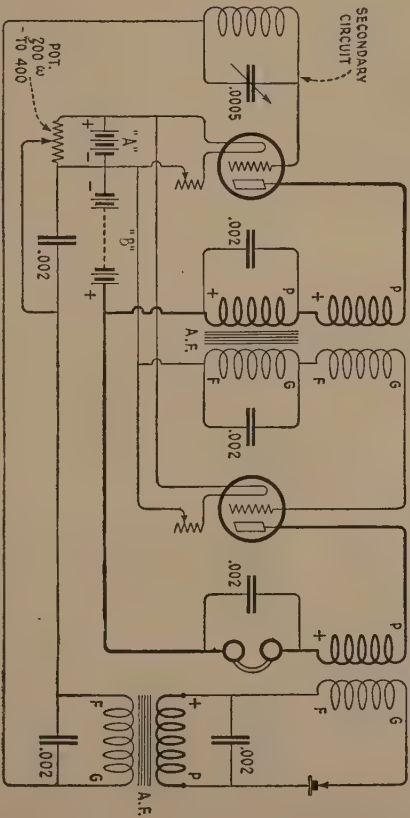
former, as shown. In the plate circuit of the tube is a radio-frequency transformer, which serves to impress the signals on the crystal detector. Following detection, the signals are passed on to the grid circuit of the tube through the audio-frequency transformer. Small fixed condensers, C-3, C-4 and C-5, are included in the combination to provide low impedance paths for the radio-frequency currents across the audio-frequency equipment. In order to prevent oscillations, a



Typical two-tube reflex receiver, in which a detector tube is used in place of the crystal detector. The values for the different components are indicated.

potentiometer is provided, as in many other radio-frequency circuits. The tuning arrangements in this case consist of a 23-plate variable condenser and two compact inductance coils, used as a coupler. Instead of the fixed transformer, a tuned radio-frequency circuit may be used, although this complicates the set and makes an additional control necessary.

So much for the most elementary of the reflex circuits. *Our next diagram shows a reflex arrangement*



the various components are indicated.

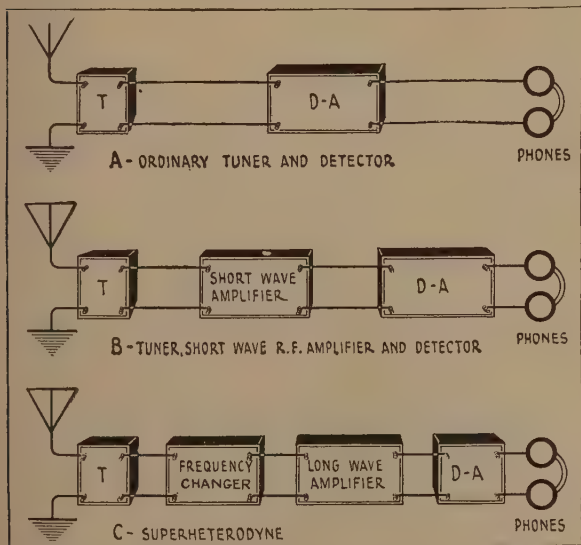
using a vacuum tube detector and a condenser-tuned radio-frequency transformer. The detector tube introduces some noises in the reception, but makes for more powerful signals than a crystal detector. Then there is still another diagram which shows how four stages of amplification—two of radio and two of audio—are obtained with two tubes and a crystal detector. No matter how many tubes may be employed in a reflex set, the general idea remains the same as shown in these simple circuits.

AND THE SUPER-HETERODYNE IDEA

The problems of radio-frequency amplification have led to the development of the famous super-heterodyne receiver. In fact, the super-heterodyne is usually looked upon as a receiving set, whereas it is really an amplifier, pure and simple, introduced in a receiving set. The basic idea underlying the super-heterodyne is to convert the incoming signal from the broadcast frequency to the so-called intermediate frequency, which is higher than audio-frequency but lower than radio frequency, and at which the signal can be amplified by means of fixed winding transformers with marvelous efficiency and to almost any extent. The intermediate frequency is generally around 30 kilocycles, or 10,000 meters wave length.

In the super-heterodyne the signal is intercepted by a loop or a very small antenna, for the reason that the receiver is super-sensitive and requires very little intercepted energy. The signal is converted from the broadcast frequency by that unit of the circuit known as the frequency-changer. The usual method is to detect the signal by means of a first detector, and then bring this signal in interference with a locally produced frequency so as to produce a beat note of the

desired intermediate frequency. A beat note, as already explained, has a frequency equal to the difference between the two frequencies which produce it. For instance, if a signal of 1,000 kilocycles is received and an alternating current of 999 kilocycles or 1,001



The development of the super-heterodyne receiver: A is the usual arrangement for a tuner and a detector and audio-frequency amplifier. B is the usual radio-frequency arrangement, preceded by the tuner and followed by the detector and audio-frequency amplifier. C represents the super-heterodyne arrangement.

kilocycles is made to interfere with that signal, a beat note of 1,000 cycles will be produced. In the super-heterodyne receiver an oscillating circuit, controlled

by means of a variable condenser so as to obtain any desired frequency, is brought into interference with the first detector and produces a beat note for the intermediate frequency, which has all the characteristics of the original signal. Thus no matter what may be the frequency or wave length of the intercepted signal, the intermediate frequency amplification is always carried on at a fixed wave length, making for utmost efficiency.

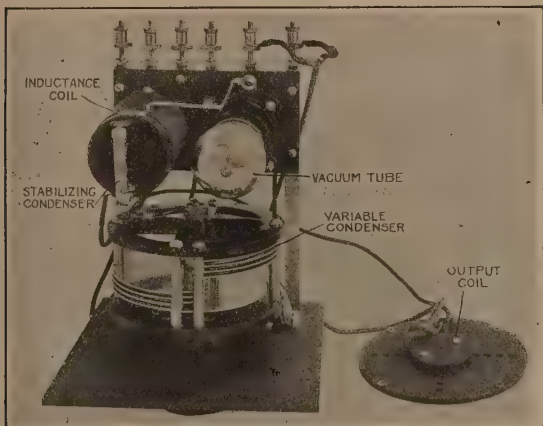
The intermediate-frequency amplifier serves to amplify the signal until it is intercepted by a second detector, which converts the intermediate frequency into audible frequency, the latter being passed through an audio-frequency amplifier and to the loud-speaker.

The usual super-heterodyne is controlled by means of two variable condensers, one tuning the wave intercepting system and in the case of a loop is placed across the leads of the loop, while the other is for the purpose of changing the frequency of the oscillator or local wave producer. The super-heterodyne is highly efficient; a six-tube super-heterodyne receiver, with a small loop, will receive signals over 3,000 miles. The super-heterodyne tunes exceedingly sharply for radio-phone signals. However, where a good antenna can be employed, it is really doubtful whether the super-heterodyne has a decided advantage over the neutrodyne and other radio-frequency receivers of the present day. Its main advantage is in the use of a very small loop for long-distance reception.

THE ULTRADYNE RECEIVER

Very much along the same lines as the super-heterodyne is the ultradyne, developed by Robert E. Lacault, well-known radio engineer and editor. In the ordinary type of super-heterodyne the first tube used as a

frequency changer is connected as a detector, with a grid condenser and grid leak. This detector rectifies the incoming signal after it has been heterodyned and the variation caused in the plate circuit is amplified through a long-wave radio-frequency amplifier, otherwise known as the intermediate frequency amplifier. In the ultradyne receiver, a different method,



Internal mechanism of the radio-frequency amplifier unit shown on page 227, with the various parts indicated. This is a one-tube tuned radio-frequency amplifier, which also acts as the tuner.

sometimes referred to as the modulation method, is employed. This method causes the incoming signal to modulate the oscillations produced locally in the same way that the speech modulates the output of the oscillator tubes in a radio telephone transmitter. This

system, which is a departure from the conventional detector arrangement, is not only more simple, but is claimed to produce a greater signal strength, which is more noticeable on weak signals. It also saves one tube, since the intermediate frequency is produced by a single tube instead of a detector tube and oscillator as in the usual arrangement.

CHAPTER IX.

INSTALLING THE RADIO RECEIVING SET

THE installation of the radio receiving set has much to do with the results obtained. An inefficient antenna, a leaky lead-in, a faulty ground connection, a mess of wires in proximity to the sensitive radio receiving set, the poor location of the loud-speaker—all these things have much to do with taking away from the otherwise excellent performance of a radio receiving set. Indeed, it is only part of the radio problem to purchase or build the best available type of receiving set. The installation of that set is of equal importance, and that, in turn, is followed by still another phase of prime importance, namely, the operation of the receiving set when once it is properly installed.

The first step in the installation of the receiving set is to settle upon the location of the antenna and the location of the receiving set. One depends upon the other, for it is important to make the connection between the antenna and the receiving set, as well as between the latter and the ground, as short and as direct as possible.

If the set makes use of a loop instead of the antenna and ground, then the matter of location is of secondary importance. A loop receiver will work almost anywhere; in fact, the loop receiver is primarily a portable proposition, intended to be used anywhere. There is virtually no installation involved in the case of the loop receiver.

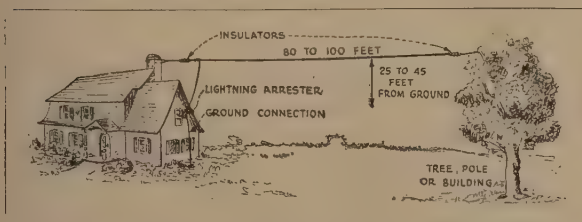
WHERE TO STRETCH THE ANTENNA

The first step in installing the usual receiving set is to select a suitable place for the antenna. There is considerable latitude in this matter. The antenna may be 50 feet long or it may be 125 feet long, or, in fact, any length from a few feet to 125 feet or over. For best results in broadcasting reception, the antenna should be about 100 feet in length, with as short a connection to the receiving set as possible. Aside from the length, the antenna should be swung as high as possible above the ground and quite clear of surrounding objects. This requirement calls for supports at either end of the antenna. Poles may be erected for this purpose, or, to economize on the installation cost, existing objects may be pressed into service for this purpose. Thus the house may be used for one support and a tree for the other. A chimney may be used as a support. The antenna may be stretched between two houses. In fact, just so long as the antenna is swung clear of the ground it will intercept the radio waves. The greater the clearance between antenna and ground below it, the better the results.

In the country the erection of the antenna is a simple matter, for there are virtually no restrictions such as one encounters in the crowded city. Thus the antenna wire may be run from the roof of the house to the roof of the barn, or even from the second story of the house

to the roof of the barn. If no barn or other out building is available, then the farther end of the wire may be supported by the clothespole or tall tree.

If necessary, a pole may be readily erected for supporting the antenna. Owing to the wide range of materials that may be used for the pole, it is not feasible to give specific details. An excellent pole may be made of one or more lengths of 2 x 4 inch sticks, spliced together by means of bolts, straps, or tightly wound wire. If such a pole is properly stayed by means of guy wires, it may be made quite rigid. Old water pipe or gas pipe makes an excellent pole, be-

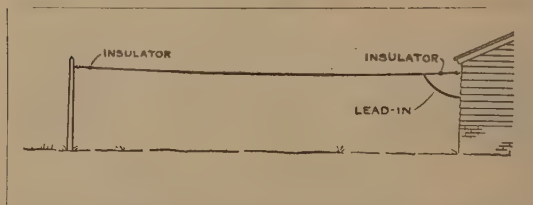


Typical arrangement for an antenna, with the single wire running from the house to a nearby tree. Note the lead-in wire, lightning arrester, and the ground wire.

cause of the ease with which the different sections can be securely coupled together. By means of reducing nipples, heavier pipe may be used for the lower sections and smaller pipe for the upper. Unless the pipe mast is to be made exceptionally heavy, it should be stayed by means of guy ropes.

In the city, the antenna presents a serious problem. What with congested conditions and a none too obliging landlord, the radio enthusiast is often forced to resort to a little strategy. The author, only recently

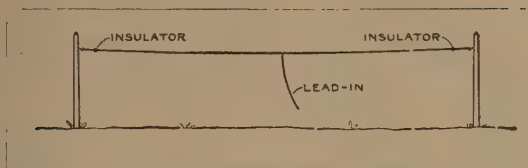
a resident of the suburbs, traveled a rather thorny path in pursuit of radio happiness while residing in New York City. One antenna after another was removed from the roof by a highly militant janitor, carrying out the instructions of an overbearing landlord. The antennæ took all kinds of forms, ranging from single wires running from one house to another across a court or large open space, to a number of wires supported on poles or supported by the dumb-waiter houses on the roof. Finally, the author simply dropped a single wire down a brick chimney, from the roof to the cellar, a distance of about 75 feet.



General arrangement of a single-wire inverted L-type antenna.

This wire was never detected, and it was tapped in the kitchen of the apartment through a flue that led into that chimney. A poor antenna at best, it served to receive all the local stations and, on occasion, the stations in nearby cities.

All sorts of improvisations may be resorted to when an outdoor antenna is not practical. A metal bedstead, the telephone line with a small fixed condenser in series, the bell wiring of the house, the electric light socket, using one of the several attachments now available for the purpose, the fire-escapes, an indoor

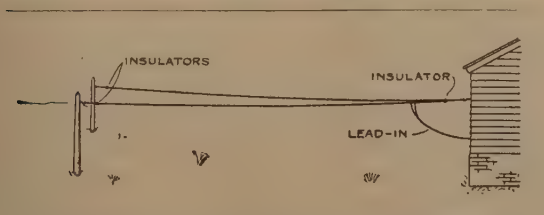


T-type single-wire antenna, which is often employed where the length of span exceeds 125 feet.

antenna of any shape and size—all these improvisations are satisfactory for nearby stations in the absence of an efficient antenna.

THE IDEAL ANTENNA

If the conditions are of the radio enthusiast's own choosing, then the thing to do is to erect a single-wire antenna, 75 to 125 feet long, as high as possible above the ground. This wire is thoroughly insulated by placing an insulator at each end. At one end—the end nearest the receiving set—the antenna wire is connected with another length of wire leading to the re-



V-type antenna, which is sometimes employed where the span is 75 feet or less, in order to increase the natural wave length.

ceiving set. This wire is known as the lead-in, and it is preferable to have it covered or insulated, so that if it touches a wall or roof coping or other object on its way to the receiving it, there will be no leakage of the evasive radio-frequency currents.

But supposing the antenna is stretched over a greater span than 125 feet, and the receiving station can be located near the middle of that span? Simple enough. The antenna we have been dealing with before is called the single-wire inverted L-type, because the straight wire and the lead-in form an inverted L-shape. If the antenna is to be, say, 200 or 300 feet long, then the tap is taken at the center, and to all intents and purposes the antenna is now the equivalent of two single-wire antennæ each 100 to 150 feet in length. In other words, the wave length of the long wire is halved by tapping it at the center. This type of antenna is known as the T-type. Another modification of this type is the V-type, in which two wires of about the same length run from the lead-in at one end, diverging horizontally to two more or less separated supports at the farther ends. This form of antenna has the same wave length as the average of the two wires, and is more efficient than a single wire.

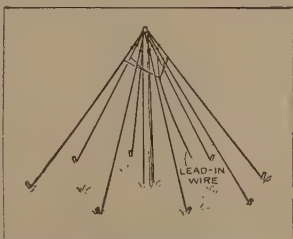
Then there is the umbrella type which must be employed where a stretch of over 40 feet is not to be had. In this case a tall pole must be used as the center support, and the wires numbering six to ten radiate downward and outward, being insulated at the top and bottom ends. The lower end of each wire should be 20 feet from the base of the pole, so as to obtain as much spread as possible. The lead-in wire is taken from the top, the various wires being connected together at their top end and spliced to the lead-in wire. The erection of the umbrella type is somewhat complicated, as compared with the simple

single-wire antenna, and is therefore not recommended for receiving purposes except in cases of absolute necessity.

For receiving purposes a multi-wire L-type or T-type antenna is not required; indeed, tests indicate that there is little gained in using more than one wire for a given span.

WIRE AND INSULATORS FOR THE ANTENNA

As for the kind of wire to use, again there is considerable latitude. Various kinds of wire are used, among these being plain aluminum wire, which has the advantage of being exceedingly light and quite low in cost; plain copper wire, which, of course, is an excellent conductor, although somewhat costly, especially in the larger sizes; hard-drawn copper, which has all the advantages of plain copper, plus greater mechanical strength; copper-clad steel wire, which has great strength coupled with good radio conductivity; stranded phosphor-bronze wire, which has long been the standard aerial wire in commercial and Government work; and annunciator or bell wire, which is insulated. The last-mentioned wire may sound freakish and merely an improvisation; but as a matter of fact the insulation has no detrimental effect. Why? Simply because if the insulation were not there, the space immediately surround-



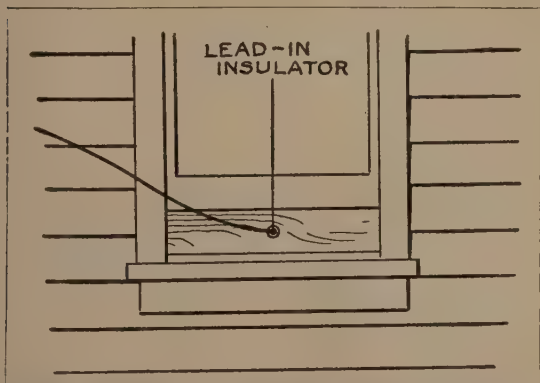
Umbrella type antenna employed where a span of only 40 feet or less is available.

ing the copper wire would be taken up by air, and the air is about as much of an insulator as the usual cotton and paraffin insulation. Hence it makes little difference one way or the other, and annunciator or bell wire recommends itself in many instances because it is so easy to obtain. A pound of No. 18 annunciator or bell wire is sufficient for a good sized single-wire antenna, together with the lead-in.

Aluminum wire is not recommended very enthusiastically by the author. Back in the early days of amateur radio, when we used to spend our hard-earned money by the quarter rather than by the dollar, aluminum wire was widely employed because a good many feet of it went with the pound. However, it has not the conductivity of copper by a good margin, and even when using No. 14 size it is not as good as No. 18 copper. Hence the gain in footage is only an illusion, since a much heavier aluminum wire must be used for the same conductivity as copper. Furthermore, it is difficult to solder aluminum wire joints, yet they should be soldered. If the joints are not soldered, water gets into them and oxidizes the aluminum wire. The oxide takes the form of a white crust, and is of such high resistance that it reduces the efficiency of the antenna quite materially. Hence aluminum wire should not be used except where cost is a prime essential, and even so, a small sized copper wire is preferable.

Copper-clad steel wire is as good as solid copper from the radio standpoint, and is certainly better mechanically. Because of its copper surface, it can be soldered like copper wire. Hard-drawn copper wire of No. 12 or 14 gauge is satisfactory for antenna construction; however, stranded silicon bronze or phosphor bronze wire is more durable and will stand greater strains.

The insulation of the antenna is accomplished by means of antenna insulators, which come in various styles. An insulator is placed at each end of the antenna wire, between that wire and the support. It is best to use the better kind of insulators, which have a series of ridges to provide a greater insulating surface. Smaller insulators, especially those of the plain white porcelain variety, may be satisfactory in dry weather but during heavy rain or snow they permit of some leakage, to the detriment of receiving efficiency.



Simple arrangement for bringing the lead-in wire into the house. A board, cut to fit in the window frame, is placed below the closed window, as here shown. A hole is bored in this board to take the lead-in insulator.

THE LEAD-IN FROM THE ANTENNA TO THE RECEIVER

The lead-in, as already brought out, is the wire that connects the antenna with the receiving set. One of the problems is to bring the lead-in to the receiving set without having it touch a coping, cornice, wall or

other object, but if it is impossible to avoid touching these or other objects, then suitable insulation should be provided. The lead-in wire itself should be heavily insulated. The usual No. 14 rubber-insulated wire used for outside electric wiring is quite satisfactory for this purpose. Even if insulated lead-in wire is used, it is well to insulate it still better by means of insulators so as to keep it away from all objects.

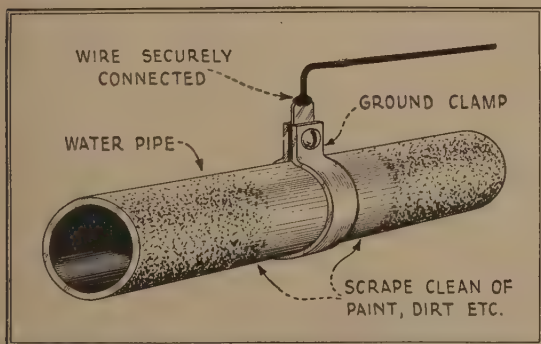
Another problem in connection with the lead-in wire is to bring it into the house and to the receiving set. Some radio enthusiasts may prefer to bore a hole through the glass pane of a window, but this is a somewhat tedious task and one that is apt to end in disaster unless there is considerable skill involved. A better plan is to cut a board to fit into the window frame below the partly raised window, as shown in the sketch on page 257. A hole is made in the board and a porcelain tube inserted, through which is passed the lead-in wire. If desired, a lightning switch or lightning arrester can be mounted on the board.

Lately there have appeared on the market several ingenious devices for bringing the lead-in wire into the house without having to bore holes in the window frame or other arrangements. These devices are generally in the form of very thin insulated strips, with connectors at each end. They are placed in the window frame and the window is pushed down on them, bending them in place with one connector outside and the other inside. The window may be shut tightly and locked, just as though the device were not being used.

THE IMPORTANT GROUND CONNECTION

Then there is the ground connection, which is highly important. Indeed, the effectiveness of the antenna

system depends largely upon the character of the ground connection. The most practical ground connection is the water supply system. Where this is not available, pipes connected with the heating or gas system may be used, although these are to be regarded with some suspicion. Sometimes an insulated joint or non-conducting length of pipe is inserted in the gas line before it reaches the earth, so that it is not a true ground connection. Most heating system pipes have lead painted joints, introducing high electrical



A good ground connection, using a water pipe if possible. Note how the pipe is scraped clean, and how the ground clamp is fastened.

resistance. However, the results obtained soon disclose whether the pipe is grounded or not.

At any rate, the pipe selected is scraped with a knife or rubbed clean with sand-paper or emery cloth until it is bright and free from paint, oxidation or plain dirt. A connection is then made by means of a ground clamp, which can be obtained at any electrical supply

or radio shop. If a ground clamp is not available, then ten or more turns of copper wire is wrapped about the clean section of the pipe and made fast to insure a perfect contact. It is best to solder the connection if possible. If no solder is used, the wire connection should be wrapped with insulating tape to prevent oxidation of the joint between copper wire and the iron or lead pipe.

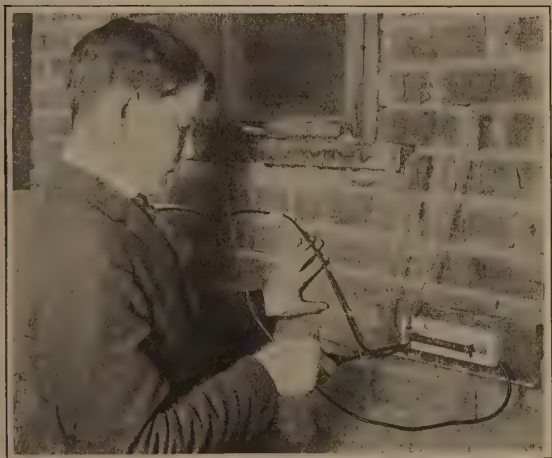
It is preferable to use No. 14 wire for the ground lead, although anything up to No. 20 will do. Naturally, the insulation is removed from the wire at the point where it makes contact with the pipe or with the ground clamp.

In instances where a water pipe or other grounded pipe is not available, it becomes necessary to use another kind of ground. Wires or plates may be buried in the earth and used as a ground connection. Such wires or plates should include an area of at least 30 square feet, buried in damp soil. Another method is to attach the ground wire to a metal bucket, which is then lowered into a well, brook, pond or lake.

DOING AWAY WITH THE GROUND CONNECTION

There are places where a ground connection is out of the question. Take, for instance, desert country, where the soil is sandy and without moisture. Or again, take rocky country where there is just a thin layer of soil over solid rock. Obviously, a "ground" is out of the question. It then becomes necessary to resort to what is known as the counterpoise, which consists of at least the same number of wires as the antenna, suspended beneath the antenna and used in place of the usual ground connection. The counterpoise wires should be elevated but a few feet above the ground, and just as carefully insulated as the antenna wires.

In aircraft, the counterpoise form of ground is employed. It must be evident that no ground connection is possible when the machine is in flight. So the antenna consists of one or more wires which are paid out while the machine is in flight, and which trail behind some 100 or more feet in length, while the ground is represented by the counterpoise made up of



Installing the lightning arrester to protect the receiving set against the heavy currents induced by nearby lightning bolts.

all the metal fittings and stay wires and control cables of the machine.

The counterpoise arrangement is especially efficient and almost necessary in conjunction with continuous-

wave transmission and reception, because it maintains rigid conditions as compared with the fluctuating conditions of many ground connections. The counterpoise arrangement is often used in short-wave C. W. transmission.

LIGHTNING AND THE LIGHTNING ARRESTER

Somehow or other radio is always associated with lightning. The laity has weird ideas about the power of a radio antenna to attract lightning and bring down destruction upon the doomed house which has a radio antenna. Yet the fact remains that the usual antenna is no more of an attraction to lightning bolts than the overhead electric light service wires, the overhead telephone wires, the gutters and leader pipes, the tin roof, the plumbing system of the house, the bathtub and so on. If radio antennæ are banished because of the fear of lightning, then, to be consistent, we should do away with the several commonplace things mentioned.

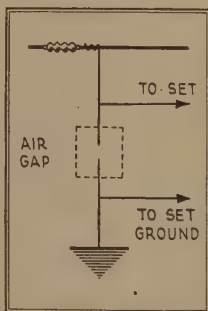
The plain truth is that there is a very remote danger of a house being struck by lightning because of the radio antenna. Furthermore, the antenna, if properly insulated and protected by means of a lightning arrester, will afford protection against lightning. It functions much after the fashion of the lightning rod, by reducing the accumulation of static electricity which goes to form the lightning bolt, and thus lessens the possibility of lightning taking place near it.

Every time a bolt of lightning is released by the thunder clouds, it sets up powerful electromagnetic waves which travel far and wide. These waves, just as radio waves, set up currents in antennæ over a wide expanse, so that the receiving set in New York City responds loudly to the lightning bolt in Chicago.

When the lightning bolt is within a few miles of a given antenna, it induces powerful currents in that antenna which seek the way to the ground. If the receiver is not protected by means of some safety device, called a lightning arrester, then the heavy currents will flow through the receiver and possibly cause damage.

It is for the purpose of taking care of such heavy induced currents that the lightning arrester has been introduced. It is a safety valve, so to speak, consisting of nothing more than a gap, either in air or in a vacuum, connected across the antenna and ground leads to the receiving set. This lightning arrester operates when the potential in the antenna rises above a certain value, and a spark jumps the gap, discharging the excessive energy to the ground without damage to the set.

To insure proper protection and to comply with the Fire Underwriters' regulations, the lightning arrester must be installed in connection with an outdoor antenna, and installed properly. No lightning arrester is required with an indoor antenna or a loop. It is preferable to have the lightning arrester ground lead as direct as possible; the ideal arrangement is to place the lightning arrester outside the building, supported some 6 to 12 inches away from the walls, and connected with a heavy copper wire that goes directly to the ground, which may be a metal plate or pipe buried in damp soil. This ground may be quite dis-



Schematic arrangement of a lightning arrester.

inct from that used for the receiving set proper. If this is not possible, then the lightning arrester may be placed indoors where the antenna lead comes in, and the cold-water pipe may be used for the ground connection. Under no circumstances should a gas pipe be used for the lightning arrester ground, for obvious reasons. According to the Fire Underwriters' rules, the wire should be at least No. 14 B. & S. gauge copper wire.

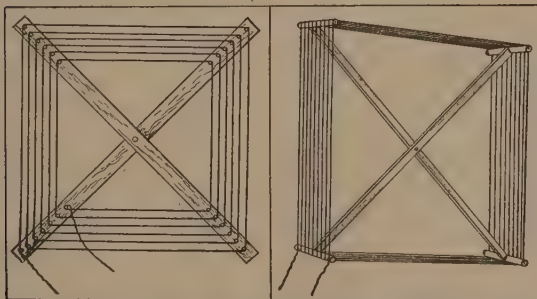
The object of the lightning arrester is to take care of induced currents, nothing else. Should the antenna be struck by a direct bolt of lightning, which is a very, very remote possibility, the lightning arrester will serve no real purpose. In that event the antenna wire will be immediately consumed by the terrific heat involved, and the lightning will leap to other objects or directly to the ground. The possibilities of the antenna being struck are no greater than those involved in the overhead electric service wires, telephone wires, plumbing system, gutters and leaders, and so on, so why worry?

THE LOOP ANTENNA AND WHAT MAKES IT WORK

The loop is an interesting device in several ways. First of all, it does away with the outdoor antenna and the ground connection, which is desirable in certain city installations, as well as in portable sets. Then, it adds a new element of selectivity because of its directive properties: it must be pointing end on toward the transmitter for the loudest reception. Again, it eliminates considerable interference both from undesirable transmitters as well as atmospheric disturbances. Finally, its principle is quite different from the usual antenna arrangement.

The loop is an inductance, rather than a condenser

as is the case with the usual antenna and ground. There is a very close parallel between the ordinary direct-current generator or dynamo and the loop antenna exposed to a passing radio wave. In the dynamo a number of coils, corresponding to the loop antenna, are rotated in a powerful magnetic field. The purpose of rotating them is that they may move with respect to the field and thus have a voltage generated in them. The amount of this voltage depends, of course, upon the strength of the field and the speed at which the wires are swept through it.



Two types of loop antennæ. The left-hand type is of the spiral design, while the right-hand type is of the helical design. Both types are widely employed, since each type has its advocates.

In the radio example the coil stands still but the field moves swiftly past the coil, thus accomplishing the same result. The speed at which the field moves cannot, of course, be varied and is always the speed of light, 186,300 miles per second.

Let us see now what form of loop would have the greatest voltage generated in it by a passing radio

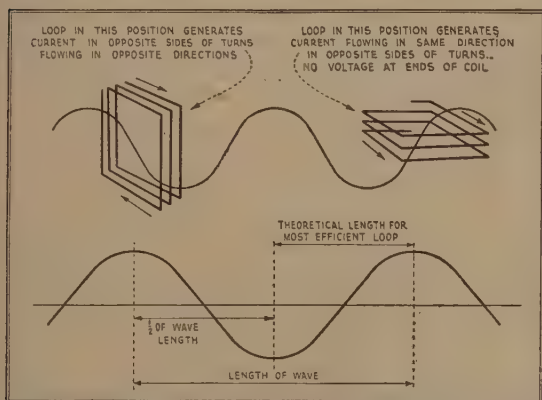
wave. Let us think of this radio wave as very much like a great smooth wave on the ocean, which, of course, also moves forward with a very definite velocity. The turns of wire on our loop antenna are necessarily in series with each other—that is to say, they form a continuous winding. If the maximum voltage is to be generated in any one turn of the loop, then the voltage generated in the two sides of this turn should be in opposite directions, so that they may add and not oppose each other. If the voltage generated in both sides of the loop were in the upward direction at any one instance, then these two voltages would cancel each other, but if the voltage on one side of the turn was up and the other side of the turn was down, then they would add, and if the loop were connected to a receiver a current would flow around the turns of the loop. This, of course, is exactly what we wish to have happen.

Now, in order to have the voltage generated on one side of the loop in the opposite direction to that generated on the other side of the loop, the loop would have to be one-half a wave length long—that is to say, it would have to be long enough in the horizontal direction so that one side was in the crest of the wave when the other side was in the trough of the wave. Since the distance between the crests of the wave is the wave length itself, then the distance from the crest to the trough is one-half the wave length.

The higher are the sides of the loop, that is, the longer are the vertical wires, the greater will be the voltage generated, and of course the voltage generated in each turn is added to the voltage generated in all the other turns.

But a loop one-half a wave length long is quite out of the question. It would be as long as a steamship and almost as difficult to handle. The loops which

we are using every day are of quite reasonable dimensions. They are only a few thousandths of a wave length long. How do they function? In order to answer this question let us ask ourselves how we would build a coil of wire in order that absolutely no voltage should be generated in it by the passing wave. The only way in which this could be accomplished would be to so build the coil that the same voltage



Graphic explanation of the action of the loop antenna. Note how the radio wave induces a current in the loop when the loop is pointed end-on towards the oncoming wave, and how it fails to induce current in the loop when the loop is placed horizontally or at right angles to the wave.

would be generated in both sides of it and that the voltages generated in the two sides would be opposed to each other. This would give a complete cancellation and no voltage at all at the terminals of the loop or coil. It is obvious that the only way in which this

could be done would be by so arranging the loop that it had no length at all. That is to say, arranging it so that the two sides were exactly in the same position in space. This would mean that the horizontal wires across the top and bottom of the loop would cease to exist and the loop would become nothing but a wire laced up and down between pegs on the plain surface of a board.

If there is any distance at all between the two sides of the loop, then there will be some difference, not in the amount of voltage generated in the two sides but in the time at which this voltage is generated, and there will consequently be some voltage at the terminals of the loop, since complete cancellation of voltages cannot occur.

WHEN THE LOOP HAS NO WAVE LENGTH

If the loop is rotated so that its horizontal wires are at right angles to the direction in which the signal is coming, then the loop has no length so far as those signals are concerned. The passing wave strikes both sides of each turn in the loop at exactly the same instant and the voltages generated are therefore equal and opposed; and there is no terminal voltage. This is, of course, the fact which gives the loop antenna its very useful directional property. It is to be noted, however, that if the loop is turned ever so slightly from this zero position, then the voltages no longer cancel and there is a voltage at the terminals. This means that the zero position of the loop is very sharp, but the maximum position is very broad.

In applying the loop antenna to an actual radio receiver it is necessary that provision be made to tune it to resonance with the desired signal. This is accomplished by means of a variable air condenser,

and since this condenser has a very definite maximum capacity the amount of inductance which the loop can have is also limited. This maximum inductance with the maximum capacity of the variable condenser must give resonance to the longest wave to be received. The specification for the best loop antenna, therefore, is that it shall have just as many turns as possible, each turn being just as long as possible and just as high as possible and still have no more than the required maximum inductance. The higher the loop is the greater will be the voltage generated in each side of each turn, and the longer it is the greater will be the difference in time at which these voltages are generated in the two sides of the loop, and consequently the greater will be the voltage at the terminals, but it must not have an inductance value greater than that required for tuning.

Now the inductance of a coil of wire increases very rapidly as the turns are wound closer together. The maximum inductance is obtained with the minimum number of turns when they are wound just as close to each other as possible. In order to get the maximum number of turns for a given inductance, which is what our loop requires, the turns should be wound just as far apart as possible.

The author is indebted to R. H. Langley, Radio Engineer, General Electric Company, for the greater part of this information on the loop type of antenna.

CONNECTING UP THE RECEIVING SET

The arrangement of the wave-intercepting system is, after all, the main part of the installation of the radio receiving set. Little remains to be done except to place the receiving set on the table or other piece of furniture on which it is to be permanently

located. Keep the set at least one foot from the wall and away from heavy metal objects, such as radiators, and so on.

Connect the "A" battery, whether it be of the dry-cell or the storage battery type, to the receiver. Place a tube in a socket and turn up the rheostat. If the tube fails to light check up the "A" battery connection. The battery should be placed under the table, with heavy wires leading up to the set. If desired, the recharger for the storage battery may be placed next to the storage battery, ready for instant use. This is a more convenient arrangement than having to carry the battery to the recharging station or to some other part of the house.

Connect the "B" batteries in accordance with the type of receiving set that is being installed. Be sure the "B" battery leads are connected to the "B" battery terminals of the receiver and not to the "A" battery terminals by mistake. Do not put in any tubes into the receiver until the set is completely wired.

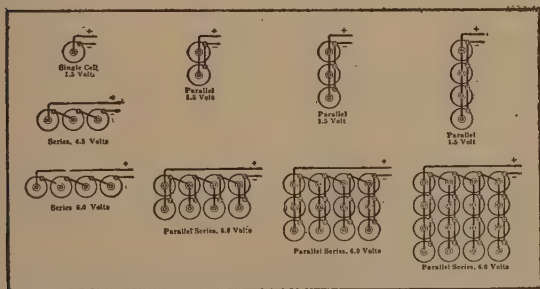
The accompanying diagram shows various hook-ups for dry cells. When several vacuum tubes are to be used, it is best to use the parallel or series-parallel arrangement so as to maintain a steady filament voltage and to increase the life of the dry battery.

Even though dry cells are called "dry," the fact remains that they contain a liquid electrolyte, usually soaked up by blotting paper or wood pulp. It is highly important to keep dry cells of all kinds in a fairly cool place. Time and again a radio enthusiast will place the dry cells, especially "B" batteries, near a radiator or on a window sill in the full glare of the sun, and then blame the radio manufacturer for their short life.

Connect the antenna and the ground leads with the appropriate terminals on the receiving set. Some sets have two antenna terminals, one marked "Short An-

tenna" and the other "Long Antenna." The best plan is to try the antenna lead first on one terminal, and then on the other, leaving it on that terminal which gives the best results. It will usually be found that when the antenna is connected on the "Long Antenna" terminal the tuning will be sharper, while the signals will be somewhat weaker. This is because a small condenser within the set is now connected in series with the antenna.

Insert in the receiver the tubes called for by the manufacturer. This is an important point. The best



Various hook-ups for dry cells, for producing different voltages. The parallel hook-ups are advantageous for the reason that they increase the life of the dry battery and deliver a steadier current.

results should not be expected if tubes other than those specified are employed.

It is important to keep the external wiring as neat as possible. Do not have a mess of tangled wires, because these are apt to cause noisy reception. Be sure that connections with batteries and receiving set terminals are tight, otherwise static will be blamed for many noises which are quite within your control. Run the leads from the antenna and ground straight

back from the receiver, rather than alongside the receiver. This is especially important in connection with super-sensitive radio-frequency receivers.

Don't fail to read the directions supplied by the manufacturer of the set. These directions usually contain a wealth of useful information on that specific set.

And now the set is ready to be operated, as dealt with in the next chapter.

CHAPTER X.

OPERATING THE RADIO RECEIVER FOR RADIO BROADCAST PROGRAMS AND DOT-DASH MESSAGES

THE day has arrived when radio receiving sets for the interception of radio broadcast programs have been reduced practically to the irreducible minimum. Anyone can operate one of these present-day receivers of the simpler kind. In fact, radio engineers have been striving toward the single control receivers, and in several instances this has been achieved without any heavy sacrifice in efficiency.

Hence this chapter, dealing with the operation of the receiver, is not as lengthy as it would have been a year or two ago. Still, there is a good deal to be said about the operation of radio receivers, since all of them are not yet reduced to the single-control fool-proof variety.

The operation of the usual receiving set involves connecting up that set, adjusting the detector, and tuning in for the signals.

IS THE CRYSTAL DETECTOR SENSITIVE?

With the vacuum tube detector, the adjustment is a simple matter. The rheostat is turned up until the filament lights, and the tube is ready to detect signals. With the crystal detector, the adjustment is a trifle fussy. The cat-whisker resting on the crystal, or the two crystals in contact, must be shifted until a sensitive spot is found, since the arrangement is not uniformly sensitive.

When the crystal detector is adjusted properly it should respond to disturbances other than the usual radio signals. Thus in the city, where there are electric light wires, telephone lines, trolley cars, elevators and other electrical appliances, the detector should respond to the electromagnetic waves given off by electrical equipment of various kinds within range. In other words, if the detector remains absolutely silent, then it is evident that no sensitive spot has been found; but if it causes clicks, scratchy sounds, buzzes and other noises to be heard in the telephone receiver, then it may be taken for granted that the detector is satisfactorily adjusted. Sometimes the sensitiveness may be tested by turning on and off a nearby electric lamp. This should produce a click in the telephone receivers. However, if a hum is heard, this should not be considered as an indication of the sensitiveness of the detector adjustment. Quite to the contrary, the hum is caused by what is known as induction, given off by an alternating current line. This hum may be picked up when the detector is not even operable, and this hum generally indicates that the members of the crystal detector are not in proper contact.

The crystal detector should preferably be adjusted when the radio broadcasting stations within range are known to be on the air. It is the uncertainty of the

crystal detector adjustment which makes this type of detector less desirable than the vacuum tube detector, and why the relatively insensitive diode or two-element vacuum tube has been gaining in favor, especially in reflex sets.

ADJUSTING THE VACUUM TUBES

With the usual vacuum tube set, the first step in its operation is to turn up the filament rheostats. Here the object is to supply the tubes with the necessary current, without overstepping the mark. Some tubes, especially the WD-11 and WD-12, burn very dimly, practically an all but invisible cherry red, and the layman is warned against turning up the rheostat too full. Tube manufacturers supply directions with their tubes, in which they tell what battery voltage to apply and also what resistance rheostat should be used. These directions should be followed to the letter, for they mean long life for the tubes and general satisfaction. Care should also be exercised to apply the proper "B" battery potential.

CARE OF THE STORAGE BATTERY

If a storage battery is used with the receiving set, it should be properly cared for, since that is a necessary part of the operation of the set. In fact, with proper care a good storage battery should last five years or more, whereas if neglected the same battery may last a year or less.

The first item in the care of the storage battery is to see to it that the level of the liquid or electrolyte is above the tops of the plates. This can be determined by unscrewing the plugs and looking into the battery. Under no circumstances light a match near

the vent of the storage battery, because such a battery often gives forth hydrogen gas which, when mixed with the oxygen of the air, is highly explosive. Use an electric flashlight, if a light is required. When the level of the electrolyte drops down below the tops of the plates, distilled water should be added until the level is about one-half inch above the tops of the plates. Pure, distilled water only should be added, which can be purchased at the drug store or the garage. Under no circumstances should ordinary water be added, because its chemical composition will ruin the storage battery plates. The water should be added preferably before the battery is placed on charge.

The storage battery, as its name indicates, is a storage for electricity. The current delivered to the battery brings about certain chemical changes, and these changes cease when the battery is fully recharged. Any further charging merely causes the battery to boil, with no useful end to gain. The electrolyte changes its chemical composition from the discharged state to the fully charged state, and it is this change, together with its accompanying change in specific gravity, which enables one to determine the state of charge of the battery. For this purpose a hydrometer—an instrument for testing the specific gravity of liquids—is employed. The hydrometer, which is already familiar to the motorist who uses it in connection with his automobile storage battery, is the instrument used to determine when the battery is fully discharged and, when placed on charge, when it is again fully charged.

A fully charged storage battery has an electrolyte of dilute sulphuric acid, and this has a density—that is to say, a weight compared to the weight of an equal amount of water—of between 1.25 and 1.3, or between 1.250 or 1.300 as a hydrometer reading. As the battery is being discharged, some of the acid,

which is naturally heavier than water, is used up in the chemical action and the density of the solution then falls down to 1,100 or 1,150 on the hydrometer scale. The hydrometer reading therefore becomes the indicator for the condition of the battery. The usual storage battery hydrometer has a glass tube with a rubber bulb, and the squeezing of that rubber bulb followed by its release causes the electrolyte to rise into the glass tube. In the glass tube is a small glass float or bob, the stem of which is marked off with graduations. The bob rises or sinks more or less in the liquid contained in the glass cylinder, and the reading is taken at the surface of the electrolyte.

Aside from the hydrometer reading, the condition of a storage battery may be determined by means of a simple storage battery indicator very much like the hydrometer. However, instead of containing a bob, it contains three colored balls, usually red, white, and green. These balls are of different specific gravities, so that if the three balls float, the battery is fully charged; if two balls float, the charge is still strong; if one ball floats, the charge is lean; and if all balls sink, the charge is practically dead and the battery is badly in need of recharging. This device is simpler than a hydrometer and is preferred by many laymen for that reason.

A voltmeter may also be employed to determine the charge of a storage battery. When the battery is fully charged, each cell should have a potential of about 2.2 volts. This potential drops down to 1.8 when the battery is in need of recharging.

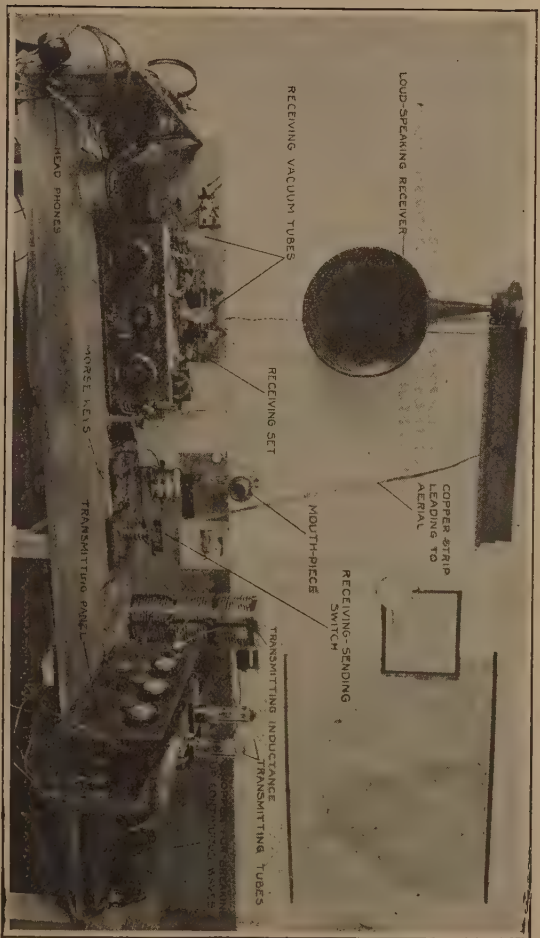
RECHARGING THE STORAGE BATTERY

The question of recharging the storage battery resolves itself into sending the battery away to a stor-

age battery station, or doing one's own recharging. Certainly the latter is a far more economical practice, and it makes one quite independent of others. Whereas the recharging of a battery usually costs 50 cents to \$1.00 when done by a storage battery station, the same thing can be done at home from the nearest electric light socket for about 12 to 18 cents, depending on the prevailing rates for electric current and upon the ampere-hour capacity of the battery.

If direct current is available, the recharging of the storage battery is a simple matter. One need merely add the necessary resistance in series with the wires coming from the usual electric light socket, connect the proper wires to the poles of the battery, and turn on the current. The simplest recharger consists of six 50-watt electric bulbs arranged in parallel with each other and in series with one lead to the current supply. The other lead goes directly from the storage battery to the current supply. However, direct current is usually not available, and the radio enthusiast must depend on alternating current supply. In this case the recharging problem involves not only the stepping down of the voltage, but also the rectifying or translating of the alternating current into direct current.

There are various types of rechargers now on the market, designed to operate on the usual alternating current supply. The three main types are the vacuum tube rectifier, such as the tungar and rectigon, the vibrator type in which the alternating current is rectified by means of a vibrating reed, and the chemical rectifier such as the balkite. It is largely a matter of opinion as to the type to employ. The author has had experience with the three types and finds talking points for each in turn. The vacuum tube type is positive and silent. The battery is connected up and



Typical amateur radio station for the transmission and reception of radio telegraph and telephone messages. Both a station and an operator's license are required for the transmission of either radio telegraph or radio telephone messages.

forgotten until the time comes to take a hydrometer reading to determine if it is fully recharged. There are no adjustments to be made, as the recharger is quite automatic in its operation. As for the vibrating type, it is noisy and not altogether automatic. It needs occasional adjustment, otherwise its rate of charge will be found to fluctuate between wide limits. It is generally provided with an ammeter, to indicate whether it is delivering its full output or whether it requires adjustment. However, it recharges at a higher rate than the usual vacuum tube rectifier or the chemical rectifier, and for that reason it is preferred by many. It will boost up a storage battery over night, whereas the other types require a longer period to accomplish the same end. When it comes to the chemical rectifier, such as the balkite recharger, we have the same advantages as in the vacuum tube type. It is automatic and silent. Furthermore, it is in the nature of a valve, in that it will recharge the battery until the latter is fully charged, whereupon the counter-electromotive force of the battery shuts off further flow of current through the recharger. Thus the battery cannot be overcharged, and it can be left on the recharger indefinitely without danger or concern. Occasionally the chemical rectifier requires water to compensate for the evaporation of its electrolyte.

It is good practice to have a recharger alongside the storage battery. Whenever the storage battery runs down, place it on charge. Do not wait until it is entirely run down. Furthermore, whenever company is expected or when some big radio event is looked forward to, place the battery on charge so as not to have it fail at the critical time.

The same thing may be said for the dry battery used for filament current in place of a storage battery. Do not wait until the batteries are fully run down.

When the filament rheostats are turned up full because of the low voltage of the nearly exhausted dry cells, buy another set of cells and have them in immediate reserve. Otherwise, the radio set is bound to lay down at the very time when it is most urgently required.

CARE OF THE "B" BATTERIES

The "B" batteries are left permanently connected to the radio set. These batteries are not being used up when the filaments are not lighted, hence they need not be disconnected at any time. It is a measure of economy and satisfactory performance to have a voltmeter on hand to test the "B" batteries. This voltmeter should read up to 50 volts, if 45-volt "B" batteries are being used. It should be of the better kind, rather than the cheap pocket variety. When the "B" batteries are new, they will indicate close to 45 volts for the standard 45-volt battery. When the reading gets down to 35 volts, it is time to throw away the battery and buy a new one to take its place. Weak "B" batteries cut down the strength of the signals and introduce noises into the reception. A voltmeter will pay for itself because, in the first place, it will indicate when the batteries are really worn out and should be thrown away, and it will prevent the throwing away of batteries that still have considerable useful life in them. The best volt-meter for this purpose is a combination instrument with a double scale, one reading up to 5 volts and intended for the testing of standard dry cells and grid biasing or "C" batteries, and the other reading up to 50 volts for testing "B" batteries.

Care should be taken not to place dry batteries, especially "B" batteries, near a radiator or in the warm sunlight, which causes them to dry out and spoil.

OPERATING THE RADIO RECEIVER

With the hundreds of varieties of receiving sets on the market, it is impossible to give precise directions for the operation of each individual variety. Fortunately, every receiving set, whether manufactured or home built, is provided with directions for its operation. These directions should be carefully read, for, after all, the designer of any set is in the best position to tell you how to operate that particular set.

Tuning the receiver—a rather late day to be telling several million listeners-in how to handle their set! Even the layman has seen enough of radio sets in the hands of others to have some idea of tuning. True, but there are ample indications that everyone does not yet know how to tune a receiving set and, what is more, is quite unaware of the fact. The bedlam of noises that occasionally mar our radio programs are due to faulty tuning. Indeed, the greatest technical problem of radio broadcasting is the elimination of the squawks, groans, shrieks, whistles and “birdies” in general, which interfere with what would otherwise be flawless reception.

The cause of these unbecoming noises is radiation. By that term the radio engineer means the transmission of radio energy by a receiving set. In the usual vacuum tube receiver, especially of the well-known regenerative type, if the tuning is carried beyond a certain point the tube no longer acts solely as a receiving tube, but begins to function as an oscillator or generator of radio waves. In this oscillating condition the receiving set now becomes a miniature transmitter, and sends out a weak radio wave that may be detected over a distance of a quarter to half a mile. This weak wave, or radiation from the receiving set, is picked up

by surrounding sets tuned more or less to that same wave length. Just so long as that weak wave is by itself, it produces no noticeable effect in the surrounding receiving sets; but as soon as another wave of practically the same wave length is received, the two waves interfere with one another and produce an audible sound or "beat note" in the telephone receivers or loud-speaker of the radio receiving sets.

No matter how elaborate may be a receiving set, it is subject to the "birdies" of nearby receiving sets in the hands of careless operators, just as the motorist on the public highway is liable to damage and injury from a careless driver. In fact, there is a striking parallel between the radio broadcasting situation and the highway courtesies; just as motorists have learned to drive carefully, dim their lights and, in general, watch out for the other fellow's welfare, so radio enthusiasts are learning that it pays to keep one's set from oscillating and interfering with the radio enjoyment of others, because by so doing the radio atmosphere must eventually be made ideal for everyone. Radio engineers and manufacturers are also working to this end by designing and manufacturing radio receivers that will not radiate, no matter how they may be handled.

TUNING THE REGENERATIVE RECEIVER

The receiving set most likely to radiate when improperly tuned is the simple but highly efficient single-circuit regenerative type. There are two controls in a set of this type, one being known as the tuning or "station selector" knob, and the other as a tickler or "intensifier" knob. The tuner knob makes it possible to tune in one station and eliminate the others, while the tickler or "intensity" knob serves to increase the

signal strength. *Both controls should be operated simultaneously.*

The single-circuit regenerative receiver is, unfortunately, in rather bad repute today because of its radiation possibilities. Yet here is a circuit which will reach out farther and give louder signal response than many of the more elaborate and more costly circuits now in use. When properly tuned, it will not radiate. The first step in its proper manipulation is to set the tickler at zero, and then bring the tuner control to approximately the setting where one expects to find the desired signal, and, with the other hand, the tickler control is brought up to the point where a slight hiss or rustle is heard. The tickler is maintained at the hissing point while the tuning control or "station selector" knob is manipulated to tune in the desired station. If the signals are not quite clear, the tickler is moved back just a trifle so as to clear up the slight hiss. The tickler should never be increased beyond the hissing point. If it is, a whistle or squeal will be heard in the telephone receivers or loud-speaker, indicating that the set is now oscillating or sending out an interfering wave. If a slight change of the tuner adjustment results in a whistle or squeal, it is an indication that the set is oscillating and radiating, even though it may otherwise be silent. This may be remedied by decreasing the regeneration or tickler adjustment, until the whistle or squeal disappears.

Then there is the regenerative receiver with three controls, one being for the station-selecting work, another for tuning the secondary or tube circuit, and the remaining one for regeneration. This type is known as the three-circuit regenerative receiver and is highly selective, although it requires considerable skill and patience to get the maximum results of which it is

capable. Since this receiver has three controls the general tendency is to set the tickler or regenerative control to maximum, and then tune the primary and the secondary until the whistle-like note of a broadcasting station is heard. All this while, the receiver is sending out an interfering wave, which is playing havoc with nearby radio receiving sets to the disgust and indignation of neighbors.

The way to operate the three controls of this receiving set is to chart or calibrate the secondary control knob for various wave lengths or stations. In some cases the manufacturers supply such data for their receiving sets. With this data on hand, the secondary control is set for the approximate wave length or the station desired, releasing both hands for the two remaining knobs. The tickler or regeneration knob is now adjusted until a slight hiss is heard as the primary or station selector control is tuned to the desired signal. Some radio authorities contend that this type of receiver should be used only when it is at a sufficient distance from other sets to preclude the possibility of interference, while other radio authorities claim that such a receiver can be made to minimize radiation and thus make it more desirable in crowded localities than the single-circuit regenerative receiver.

TUNING THE RADIO-FREQUENCY RECEIVER

It is the regenerative receiver that is blamed for radiation troubles, while other types escape comment, as a rule. This, however, is unfair, and is based on an incomplete knowledge of radiation possibilities. Sets in which radio-frequency amplification is employed are sometimes guilty of radiation, because oscillations may be set up in the amplifier tubes. In the better types

of radio-frequency receivers the oscillating tendencies are overcome by a potentiometer or stabilizer control or by some neutralizing device, such as the tiny neutralizing condensers of the well-known neutrodyne receiver. Where a potentiometer or stabilizer, as it is sometimes called, is employed, the operator should remember at what points the potentiometer or stabilizer is placed to remove the whistle in his own 'phones or loud-speaker, and always move the potentiometer up to that point before adjusting the tuning controls.

The simplest manner by which to tell whether a tube is oscillating or not is to tap the grid connection, and if clicks are heard it is an indication that the tube is exceeding the regenerative point. Sometimes one can obtain the same effect by tapping the antenna binding post of the receiver, but the grid is the only reliable contact. If one adjusts the set too far in regeneration, the signals become mushy and indistinct.

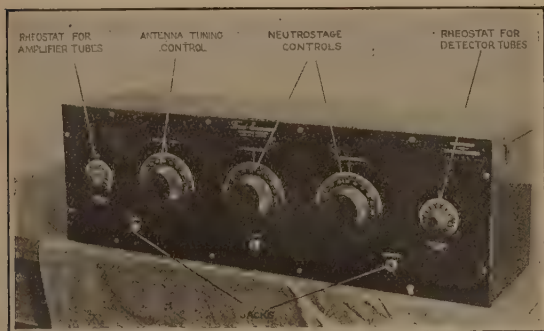
GETTING THE MOST OUT OF THE RECEIVER

After all, the receiving set is very much like a musical instrument, in that the person who uses it day in and day out is enabled to get more out of it than the newcomer. The best practice is to read the directions of the manufacturer or the designer, as already suggested, since these directions apply particularly to the set in question.

A receiving set may be sharply tuned or not, according to desires and conditions. Thus in the case of a nearby station the signals of which come in too loud, the operator may detune the signals so as to do away with the harshness of the signals. It is surprising what can be accomplished through careful detuning. Thus in the case of an elaborate receiving set with several stages of tuned radio-frequency amplification,

such as the neutrodyne, it is possible to detune one or more of the controls and do away with considerable static during the warm weather. Of course, this cuts down the signal strength, but through proper detuning the static is reduced faster than the signals.

During summer weather, when there is plenty of static in the air, the operator of a receiving set will find his ability taxed to the limit more than once. The static at times comes through louder than the signals, unless one is favored with a nearby broad-



Neutrodyne receiver with the usual three tuning controls and the two filament controls. This type of receiver is simple to tune, yet gives remarkable results. Once the three dials are adjusted for a given station, that same station can be picked up again by setting the dials for the original combination.

castings station. When confronted with such conditions the operator should try his head-phones directly after the detector, eliminating the audio-frequency amplification. If a loud-speaker must be used, it should be connected with only one stage of audio-frequency amplification. Also, a smaller antenna should be used

than during cold weather. These measures often help materially. In fact, in real long-distance reception, whether in summer or in winter, the most satisfactory results are generally obtained without audio-frequency amplification. The signals may be quite weak, but at least they are fairly pure and free from extraneous noises and distortion due to audio amplification and conditions in the receiving circuit.

FROM RADIO-PHONE TO DOTS AND DASHES

Sooner or later, and better sooner than later, the radio enthusiast turns to dots and dashes because, after all, the radio telegraph still dominates the air as far as the volume of traffic is concerned. While the music and the radiophone talks may be most interesting to the laity, the fact remains that many things of great importance are being missed if one does not understand the telegraph code.

Formerly, the Morse telegraph code was largely employed in radio telegraph work in this country. At that time the Marconi land stations and ship installations used the Continental code, which is the present code, while Morse is used on our telegraph lines, and Government and amateur stations used the Morse. However, in order to have a uniform code with the rest of the world, the Continental code was finally adopted as the standard radio code. This code differs from the former Morse code in the fact that it has no spaces between the letters themselves. In the Morse code, for instance, the letter C is represented by dot dot space dot. The letter R is just the reverse, namely, dot space dot dot. Now, since there are spaces between the letters themselves, it stands to reason that the space between the dots and dashes forming a single letter must be shorter than those between

letters, and it is this feature which makes the code more complicated and more liable to error than the Continental code, which has no spaces within the letters themselves.

The Continental code may be readily mastered with a little patience. The best method to proceed in learning the telegraph language is to learn the code letters not so much by remembering the dot and dash combinations as by learning the sounds. In other words, when an operator listens to a telegraph message he does not notice the dot and dash combinations of each letter and then translate these combinations into the proper letter or numeral. Instead, he catches the certain sound or combination of each letter or numeral, and automatically his trained mind reads off the message in letters. The trained operator never thinks of the letters in dots and dashes, just as the reader, in reading this line of type, does not notice the letters in each word but recognizes words as complete units by their general appearance. In writing, the same is true. The rapid writer does not think of each letter as he writes; his words are his units, and he writes as he thinks.

MASTERING THE TELEGRAPH CODE

Therefore, the code must be learned by means of some instrument which simulates radio dots and dashes. For this purpose a simple buzzer operated by a battery and a telegraph key, may be used. Again, one can purchase a regular practice set, which has buzzer and key combined in one unit. A most ingenious little practice set is available for this purpose, containing a battery, buzzer, telegraph key, and a lamp for visual signals.

The first step, once the practice set is at hand, is to

learn the code letter by letter. The code is given in the chart on facing page. Note that A is a dot and a dash. This is translated into a short snappy push on the telegraph key followed by a longer push. The key should be held with the index and middle fingers of the right hand resting lightly but firmly on top of the knob, with the thumb in light contact at the side or beneath the rim of the key knob. All characters should be made by wrist motion, with the elbow stationary, and all muscles of the arm and fingers should remain perfectly flexible. One of the most difficult things for the beginner to learn is proper wrist motion, which is so essential to good transmitting. The beginner should never start with the key knob close to the table, due to the fact that this will interfere with the forearm and free wrist movement. Transmitting involves a downward pressure on the key of short or long duration, it being unnecessary to do any elevating of the key as this is provided for by the spring compression under the key.

The beginner should first learn to recognize the letters of the Continental or International code instantly when heard, without conscious effort. In order to acquire this knowledge he should start to send at a slow rate of speed, remembering that a dash is equivalent in duration of time to that taken for making three dots. When operating the key, listen to the sound produced by the buzzer, or, if the practice set has a visual indicator such as a lamp, watch the flash produced by the blinker, as it is called. In a surprisingly short time smoothness and speed in both sending and receiving will be developed. In some practice sets a head receiver is worn so that the buzzes are heard in the same manner as though they were received from a radio telegraph transmitter.

Taking the telegraph code, the beginner should start

DEPARTMENT OF COMMERCE
BUREAU OF NAVIGATION
RADIO SERVICE

INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS

TO BE USED FOR ALL GENERAL PUBLIC SERVICE RADIO COMMUNICATION

1. A dash is equal to three dots.
2. The space between parts of the same letter is equal to one dot.
3. The space between two letters is equal to three dots.
4. The space between two words is equal to five dots.

A . —	Period
B — . . .	Semicolon
C — . — .	Comma
D — . .	Colon
E .	Interrogation
F . . — .	Exclamation point
G — . .	Apostrophe
H	Hyphen
I . .	Bar indicating fraction
J . — — —	Parenthesis
K — . .	Inverted commas
L . — . .	Underline
M — —	Double dash
N . .	Distress Call
O — — —	Attention call to precede every trans-
P . — . .	mission
Q — — .	General inquiry call
R . . .	From (de)
S . . .	Invitation to transmit (go ahead)
T —	Warning—high power
U . . —	Question (please repeat after)
V . . .	interrupting long messages
W . — —	Wait
X	Break (Bk.) (double dash)
Y — . —	Understand
Z — . . .	Error
Å (German)	Received (O. K.)
Ä or Å (Spanish-Scandinavian)	Position report (to precede all position
CH (German-Spanish)	messages)
Ê (French)	End of each message (cross)
Ñ (Spanish) —	Transmission finished (end of work)
Ö (German) —	(conclusion of correspondence)
Ü (German)	
1 . — — —	
2	
3	
4	
5	
6 . — . . .	
7 —	
8	
9 —	
0 — — — —	

with the first four letters, mastering them in turn. Thus, the beginner will note by studying the code chart that dah de dah de—and not dash dot dash dot—is C, instantly, and that dah de de de is B. In other words, he learns what sounds represent each letter, and he does not stop to figure how many dots and dashes he has heard. It is left to the mind to perform two functions for each letter, namely, to think of the symbol and then the letter. It will be found that as the code is mastered, the letters will form in the brain automatically, and when this stage is reached the speed can be greatly increased.

After mastering the first four letters, the beginner goes on to the next four. With these mastered, he repeats all the letters from the beginning again, and then passes on to the next four, and so on. It may require several evenings to memorize all the letters and numerals, and finally one can go on to the various punctuation marks and other characters. To recognize the symbols instantly, even when they are sent at slow speed, takes much longer, of course. Sending is much simpler than receiving.

With all the symbols memorized, the beginner should sit down by the hour and translate newspaper articles or magazine articles or any other "copy" into the Continental code, using the practice set. In this manner he trains his ear to the various sounds, and after all the mastering of the code is just that, nothing more.

The next step is one which presents two alternatives: Either the beginner can get in touch with some other beginner and spend some time each week transmitting messages back and forth to each other by means of a buzzer practice set, or the beginner can listen in on his receiving set to the amateur transmitting stations, endeavoring to pick up letters here and

DEPARTMENT OF COMMERCE

BUREAU OF NAVIGATION

RADIO SERVICE

INTERNATIONAL RADIOTELEGRAPHIC CONVENTION

LIST OF ABBREVIATIONS TO BE USED IN RADIO COMMUNICATION

ABBREVIATION	QUESTION	ANSWER OR NOTICE
PRB	Do you wish to communicate by means of the International Signal Code?	I wish to communicate by means of the International Signal Code.
QRA	What ship or coast station is that?	This is
QRB	What is your distance?	My distance is
QRC	What is your true bearing?	My true bearing is degrees.
QRD	Where are you bound for?	I am bound for
QRE	Where are you bound from?	I am bound from
QRG	What line do you belong to?	I belong to the Line.
QRH	What is your wave length in meters?	My wave length is meters.
QRI	How many words have you to send?	I have words to send.
QRK	How do you receive me?	I am receiving well.
QRL	Are you receiving badly? Shall I send 201 for adjustment?	I am receiving badly. Please send 20.
QRN	Are you being interfered with?	I am being interfered with.
QRN	Are the atmospherics strong?	Atmospherics are very strong.
QRO	Shall I increase power?	Increase power.
QRP	Shall I decrease power?	Decrease power.
QRQ	Shall I send faster?	Send faster.
QRS	Shall I send slower?	Send slower.
QRT	Shall I stop sending?	Stop sending.
QRU	Have you anything for me?	I have nothing for you.
QRV	Are you ready?	I am ready. All right now.
QRW	Are you busy?	I am busy (or: I am busy with). Please do not interfere.
QRX	Shall I stand by?	Stand by. I will call you when required.
QRY	When will be my turn?	Your turn will be No.
QRZ	Are my signals weak?	Your signals are weak.
QSA	Are my signals strong?	Your signals are strong.
QSB	Is my tone bad?	The tone is bad.
QSC	Is my spark bad?	The spark is bad.
QSD	Is my spacing bad?	Your spacing is bad.
QSE	What is your time?	My time is
QSF	Is transmission to be in alternate order or in series?	Transmission will be in alternate order.
QSG		Transmission will be in series of 5 messages.
QSH		Transmission will be in series of 10 messages.
QSI	What rate shall I collect for?	Collect
QSK	Is the last radiogram canceled?	The last radiogram is canceled.
QSL	Did you get my receipt?	Please acknowledge.
QSM	What is your true course?	My true course is degrees.
QSN	Are you in communication with land?	I am not in communication with land.
QSO	Are you in communication with any ship or station (or: with)?	I am in communication with (through).
QSP	Shall I inform that you are calling him?	Inform that I am calling him.
QSQ	Is calling me?	You are being called by
QSR	Will you forward the radiogram?	I will forward the radiogram.
QST	Have you received the general call?	General call to all stations.
QSU	Please call me when you have finished (or: at o'clock)?	Will call when I have finished.
*QSV	Is public correspondence being handled?	Public correspondence is being handled.
QSW	Shall I increase my spark frequency?	Please do not interfere.
QSX	Shall I decrease my spark frequency?	Increase your spark frequency.
QSY	Shall I send on a wave length of meters?	Decrease your spark frequency.
QSZ		Let us change to the wave length of meters.
QTA		Send each word twice. I have difficulty in receiving you.
QTE	What is my true bearing?	Repeat the last radiogram.
QTF	What is my position?	Your true bearing is degrees from Your position is latitude longitude.

* Public correspondence is any radio work, official or private, handled on commercial wave lengths.

When an abbreviation is followed by a mark of interrogation, it refers to the question indicated for that abbreviation.

there. The second method is not apt to produce immediate results, for the reason that much of the traffic is entirely too fast for the beginner. However, certain radio telegraph broadcasting stations have the beginner very much in mind these days, and transmit at a very slow speed in order to furnish practice for the beginner. There are automatic machines which send messages at any desired speed for training the beginner. This is an excellent self-instructor.

One method of learning the code is to attend a radio school. The schools, thanks to their wide experience, have perfected methods of training beginners which produce early results. But in the main one can teach one's self if sufficient patience is exhibited. Listening to radio telegraph stations and attempting to jot down on paper as many letters as are recognized finally results in copying more and more letters and words until perfection is attained.

Aside from the telegraph code, there are certain abbreviations that have been inaugurated by the International Radio Convention. The list of these abbreviations is presented on page 293, and while it may not necessarily be memorized, it is well to remember the more important ones.

WHEN AND WHERE A RADIO LICENSE IS NECESSARY

Having mastered the code and become a radio operator of more or less ability, a person can consider a transmitting set. Otherwise a transmitting set is out of the question, unless one has a licensed operator to run it. The owner of an amateur transmitting station must obtain a station license before it can be operated if the signals radiated therefrom can be heard in another state, and also if such a station is of sufficient power to cause interference with neighboring

licensed stations in the receipt of signals from transmitting stations outside the state, which means that virtually all transmitters must be licensed. These regulations cover the operation of radio telephone stations as well as radio telegraph stations.

Station licenses can be issued only to citizens of the United States, its territories and dependencies.

Transmitting stations must be operated under the supervision of a person holding an operator's license, and the party in whose name the station is licensed is responsible for its activities.

The Government licenses granted for amateur stations are divided into three classes as follows:

Special Amateur Stations, known as the "Z" class of stations, are usually permitted to transmit on wave lengths up to approximately 375 meters.

General Amateur Stations, which are permitted to use a power input of 1 kilowatt and which cannot use a wave length in excess of 200 meters.

Experimental Stations, known as the "X" class, and school and university radio stations, known as the "Y" class, are usually allowed greater power and also allowed the use of longer wave lengths at the discretion of the Department of Commerce, which has charge of the granting of licenses and the enforcement of the radio laws.

All stations are required to use the minimum amount of power necessary to carry on successful communication. This means that while an amateur station is permitted to use, when circumstances require, an input of 1 kilowatt, this input should be reduced or other means provided for lowering the antenna energy when communicating with nearby stations in which case full power is not required.

Malicious or wilful interference on the part of any radio station or the transmission of any false or frau-

duleut distress signal or call is prohibited. Severe penalties are provided for violation of these provisions.

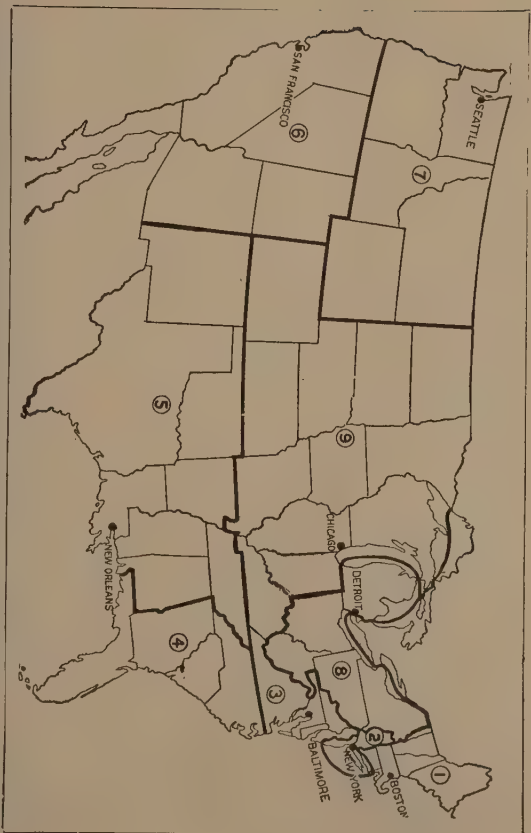
Special amateur stations may be licensed at the discretion of the Secretary of Commerce to use a longer wave length and higher power than general amateur stations. Applicants for special amateur station licenses must have had two years' experience in actual radio communication. A special license will then be granted by the Secretary of Commerce only if some substantial benefit to the science of radio communication or to commerce seems probable. Special amateur stations located on or near the sea coast must be operated by a person holding a commercial license. Amateur station licenses are issued to clubs if they are incorporated, or if any member holding an amateur operator's license will accept the responsibility for the operation of the apparatus.

Applications for operator's and station licenses of all classes should be addressed to the Radio Inspector of the district in which the applicant or station is located, or, if this is not known, to the Bureau of Navigation, Department of Commerce, Washington, D. C. The accompanying map indicates the territory covered by each radio district.

Each district has a Radio Inspector, whose address is given below:

First District.....	Boston, Mass.
Second District.....	New York City
Third District.....	Baltimore, Md.
Fourth District.....	Norfolk, Va.
Fifth District.....	New Orleans, La.
Sixth District.....	San Francisco, Calif.
Seventh District.....	Seattle, Wash.
Eighth District.....	Detroit, Mich.
Ninth District.....	Chicago, Ill.

Once more, let it be clearly understood that no li-



Radio inspection districts of the United States. Each district has a Radio Inspector, whose address is given in the table on the facing page. The call letters of the amateur transmitters are preceded by a numeral indicating the radio inspection district in which they are located.

cense is required for a receiving set only or by the operator of a receiving set. However, all persons are required by law to maintain secrecy in regard to any messages which may be overheard. This is a blanket law, of course, intended to safeguard the interests of those transmitting and receiving private dispatches and special press reports, and does not apply to broadcasted telegraph and telephone services.

Persons who wish to operate a transmitting set must apply to the radio inspector of their district for the necessary form and, at an appointed time, undergo an examination which covers their proficiency in receiving and sending telegraph messages, as well as in the theory and practice of radio. Operator's licenses are of the amateur and commercial grade, depending on the proficiency of the person examined. There is no fee or charge for either an operator's or a station license.

Every person engaged in any form of radio communication should have a copy of a pamphlet, "Radio Communication Laws of the United States," which can be secured by sending fifteen cents (not in stamps) to the Superintendent of Documents, Government Printing Office, Washington, D. C.

The laws regulating the operation of private radio stations in Canada are different in several respects from those in force in the United States. For instance, a station which is used only for receiving must have a station license. For authoritative information, inquiry should be made of the Deputy Minister of the Naval Service, Ottawa, Ontario.

CALL LETTERS AND WHAT THEY MEAN

All radio transmitters have call letters. Just as automobiles carry license plates with the State and a

number plainly marked on them, so do all radio transmitting stations use call letters consisting of two or three or four letters and numerals. If one station wishes to call another station, it calls by means of the call letters of the desired station. The Government assigns call letters at the time the station license is granted. Every radio amateur should have a copy of the pamphlets "Amateur Radio Stations of the United States," and "Commercial and Government Radio Stations of the United States." The price of each of the pamphlets is fifteen cents, and orders should be sent to the Superintendent of Documents. These pamphlets contain lists of the amateur and commercial and Government stations in the United States, and of the call letters assigned to the stations. A new edition of each pamphlet is published on June 30 of each year. A monthly publication called the "Radio Service Bulletin" is issued which contains information regarding changes in the radio regulations and traffic.

RADIO TROUBLE-SHOOTING

There are many things that can happen to a complete radio installation that are not due to any fault of the receiver itself, but can be traced to some fault in the accessories, faulty connections to batteries or antenna, poor antenna or ground, also to a number of other sources in no way actually connected to the installation itself, and which are very difficult at times to locate.

The following suggestions, for which we are indebted to the engineering staff of the Eagle Radio Company, are offered as the cause of many troubles that may come up, and the probable remedy in most cases is obvious:

*Trouble**Causes**Tubes will
not light up*

Defective "A" battery connections to the receiver or battery.

Springs on the jacks not making contact.

Defective, burnt out, tubes.

Rheostats not turned up far enough.

No signals

"A" or "B" batteries not connected properly.

Defective tubes.

Broken phone, or loud speaker cords.

Antenna grounded, through defective insulators, or by touching an uninsulated object.

Poor, or no connection, between tube prongs and springs in sockets.

Springs on the jacks not making proper contact.

Phone plug not making contact in jack.

Batteries not connected.

Batteries run down.

*Rasping
or scratchy
noises*

"B" batteries run down.

Broken phone or loud speaker speaker cords.

Loose, or dirty, battery connections.

Dust or dirt between the plates of the variable condensers.

Dirty prongs on bottom of tubes.

Defective tubes.

Atmospheric static.

*Muffled
signals*

"A" battery run down.

Too high a "B" battery voltage, do not use over 100 volts.

"B" battery run down.

*Frying,
crackling
and similar
noises*

These noises are most noticeable on distant or very weak stations, and cannot be blamed on the receiver. It is a difficulty encountered in long distance reception with a very sensitive receiver, and is the limiting factor in distance reception. This receiver is actually picking up, and amplifying, very weak electrical disturbances caused by leaky power transformers and insulators, X-ray and violet ray apparatus, smoke precipitators, faulty connections on electric railway installations, electric elevators, electric flasher signs; in fact, disturbances from any piece of electric apparatus that causes sparking in its operation. The only remedy for these noises is to reduce the length of the antenna until the noise is eliminated or until it is reduced to the point where it is no longer bothersome.

You may determine whether this noise is in any way due to batteries, or some defect in the receiver, by disconnecting antenna and ground; if the noise still persists look over your batteries; should the noise still be there after going over all these things the trouble is in the receiver itself, and the best thing to do is to return the receiver to the factory for inspection.

There are some locations, especially in cities, where these noises cannot be eliminated and perfect reception is impossible.

"Gassing" or over-charged storage batteries will also cause these noises.

Before blaming the receiver for any "noise," a very good thing to try is—open the main switch where the electric current enters the building, and then listen-in; if the noise stops it is in some way due to your electrical installation.

Antenna too long for a very sensitive receiver, in that particular location.

Poor connections in the antenna or ground circuit. Located very close to the transmitting station.

Tube not making proper contact with the socket.

Defective tube.

"B" battery wire to that tube broken.

Internal tube capacity of that particular tube being so much different from the average value, that the capacity is not neutralized. (This applies to radio-frequency receivers and to neutrodyne sets in particular). It is a good plan to try the tubes in different sockets until the best results are obtained.

Receiver improperly balanced at the factory. This is probably the least likely thing to be wrong with a reliable make of neutrodyne receiver, as great care is taken in the factory to see that the balance or neutralization is correct with the average capacity.

Be very sure it is an oscillation before going any further, not a beat note caused by two transmitters on almost the same wave length, or by a nearby oscillating regenerative receiver.

Too high a "B" battery voltage being used. Do not use higher voltage than that specified.

Imperfect ground connection.

Antenna lead-in wire running close to or parallel to the battery wires.

Antenna lead-in wire running along the back or top of the receiver cabinet, and not directly away from it.

Loud speaker, or phone cords not running directly away from the receiver.

"B" batteries run down.

Metal objects on top of, or near the cabinet.

Antenna wire parallel, or close to, high voltage transmission lines.

Ground wire in proximity to high voltage lines.

Burned out secondary in audio-frequency transformer.

Electric lights located too close to the receiver cabinet, or to lighting wires running parallel and close to the battery antenna or ground wires.

Imperfect loud-speaker.

Radio-frequency amplifier oscillating (see above under "tubes oscillating").

Defective tubes.

Batteries run down.

Inner springs of the detector jack not making contact with the other springs when the plug is not in the detector jack.

"B" batteries too weak or run down.

Receiver tunes broadly

Tube may be removed from the socket and signals heard

Tubes oscillate

Humming, sounds

Distortion

No amplification (1st stage)

	Amplifier or detector rheostat not turned up high enough.
	Amplifier tube not making contact with the socket springs.
(2nd stage)	Same as the above and also look to the following. The same jack trouble with the 1st stage jack as there might be with the detector jack.
Constant howling or whistling	Tubes not being operated correctly, turn up the amplifier rheostat. Nearby oscillating regenerative receiver. Another broadcasting station on almost the same wave length will cause a "beat note," or a whistle.
Signals seem choked	"A" battery should be recharged. Defective loud speaker. Defective tubes. "B" battery run down. "B" battery voltage too high. Defective tube.
Poor amplification	Batteries run down. Defective, or worn out tube. Tubes not making proper contact in the sockets.
Fading or "swinging" signals	When signals fade in and out gradually there is no known remedy, providing your antenna is rigid. This phenomena will be most evident on distant stations.

THE TROUBLES OF VACUUM TUBES

With the plain tungsten filament type of vacuum tube, it lives its life in a normal manner befitting any kind of electric lamp, and then burns out. When the filament ceases to light, that tube is simply through working. With the special filaments such as the oxide-coated type and the thoriated or activated type, however, the filament does not necessarily cease to light as an indication of the failure of the tube to perform. The reason for this is that there are elements employed to furnish the flow of electrons other than the mere heating of the filament.

When the oxide-coated tube fails to function properly, it is fair indication that the coating is exhausted and the tube is no longer available for good work. In the case of the thoriated or activated filament, such as the UV-201-A, C-301-A, UV-199 and C-299, excessive filament voltages tend to reduce the electronic emission to the extent that the tube is tem-

porarily deprived of its sensitiveness and amplifying properties. The use of excessive filament voltages over extended periods will gradually cause a decrease in emission which may not be noticed immediately, but which will become evident after several hundred hours of use.

When a decrease in electronic emission occurs from the cause stated, the normal sensitiveness and amplification of the thoriated or activated filament can be restored by a simple process known as "reactivation," as follows:

(1) Place the tube in the socket of the radio set, disconnect the plate battery and apply a voltage to the filament terminals 10 per cent in excess of the normal rated voltage (use accurate voltmeter).

(2) This means that 3.3 volts should be applied to the UV-199 type and 5.5 volts to the UV-201-A.

(3) The application of this voltage should extend over a period of from 2 to 15 hours, depending upon the extent to which the electronic emission has decreased.

(4) To determine when the sensitiveness of the tube has been restored the filament voltage should be reduced to normal and the tube connected in a standard radio set in the usual way. This may be done at the expiration of 5, 10, or 15 hours, and if at the end of any of these testing periods the tubes operate satisfactorily, a continuation of the reactivation process is no longer necessary.

All of which may seem strange to one who does not know just what takes place in the thoriated or activated filament. Such a filament has the supply of electrons trapped within its mass, and the normal heat of the incandescent filament tends to bring these electrons to the surface where they form a heavy coating over the filament. Then, as the heat continues,

the electrons are attracted as though by a magnet and fly off from this coat to impinge on the plate or the grid, while other electrons come out of the mass and renew the coating. If too much heat is applied, the coating is evaporated, so to speak, and momentarily destroyed. It now becomes necessary to restore it by applying excessive heat for a protracted period, and to remove the positive or plus charge on the plate so as not to draw off the electrons on the surface as rapidly as they go towards making the coating. Thus we again rebuild a surface or coating of electrons and restore the tube to its normal condition, as long as there is active material available within the filament.

CHAPTER XI.

DOT-DASH AND FACTS-AND-FIGURES BROADCASTING: FROM MARKET NEWS TO TIME SIGNALS

WHILE the jazz dance selections and the vaudeville artists may comprise the main attraction of the radio receiving set, the fact remains that behind this entertainment there is much of substantial value in the possession of a radio receiver. To the farmer the radio receiving set means the radio market news service, which brings to him the latest information on live stock and meats, dairy and poultry products, fruit and vegetables, hay, feed and seed, and some other commodities. He may be located in the rural wilds, far removed from the nearest railroad station and village; yet through the radio market news service he knows precisely what his products should bring on the market.

Then there are the weather forecasts and storm warnings, of interest to everyone. Weather, after all, is a universal subject. Our lives are largely governed by the weather. Our plans for tomorrow are altered according to the weather forecast. And the radio

weather forecast is by far the most valuable of all weather forecasts, for the reason that it reaches us fresh from the Weather Bureau, without the loss of time that is involved in the published forecasts of the newspapers.

Another important if apparently unattractive feature of the radio service are the time signals, sent out by various naval stations and also relayed by certain broadcasting stations. These time signals enable anyone with a radio receiving set to adjust chronometers by means of the broadcasted signals.

Hence at this point it is well to have a few words about the various radio services that are not generally classified with the run of broadcasting features.

RADIO MARKET NEWS SERVICE

The Radio Market News Service of the Federal Bureau of Agricultural Economics has been developed from a desire to make its crop and market news more immediately available to all who may have a use for it. Ever since the inauguration of the first Market News Service on fruits and vegetables in May, 1915, the specialists of this Bureau have given continuous study to the problem of supplying crop and market news on agricultural commodities to those who may have use for such information as quickly as possible after it can be obtained. The Market News Services of the Bureau cover live stock and meats; dairy and poultry products; fruit and vegetables; hay, feed and seed, and some other commodities associated with these four general groups. The information is supplied to producers, shippers, dealers, brokers, commission men, manufacturers, warehouse-men, administration and extension workers, banks, agents for transportation companies, chambers of commerce, co-

operative buying and selling organizations, and other commercial, extension and educational agencies.

It is the function of the Bureau to gather and assemble crop and market information from all reliable sources and distribute it in such a way as to make it available to the greatest possible number who wish to use it. In performing this function it utilizes and cooperates with all interested agencies. It affiliates with State Agencies whether they have or have not similar functions with respect to the State Government as the Federal Bureau has to the Federal Government. It utilizes information from the railroads relative to shipments and movements and collects its market information from buyers and sellers on the market at the time sales are made. In one way or another, it assembles information from every available source from which it can be obtained.

BROADCASTING THE RADIO MARKET NEWS SERVICE

In utilizing radio as a means of disseminating crop and market information, the Bureau of Agricultural Economics is taking advantage of a new art which has possibilities for communication possessed by none that have been used in the past. This new method makes it possible for all who wish the information which is broadcast to help themselves to it by equipping themselves with suitable receiving sets. The advantages of broadcasting information by radio are: (1) that the information can be intercepted and copied by means of suitable equipment at any point within certain approximate limits regardless of whether such a place is connected with the rest of the world by railroad, telegraph, or any other of the ordinary means of communication; and (2) the transmission of news is instantaneous.

During the past few years the use of radio as a means for broadcasting entertainment, news, crop and market reports, speeches, and music has developed so rapidly and has attracted such widespread interest that there are at the present time hundreds of commercial radio broadcasting stations within the territorial limits of the United States. About 150 of these stations broadcast information originating in the Department of Agriculture, including weather, crop and market reports.

Realizing the fact that farmers and those who live in small country towns are less fortunately located with respect to information and entertainment, the broadcasting stations have seen that by building their programs to meet the needs of these isolated communities that they were building for the future, for if there is any group of people in the country to whom radio makes a real appeal it is the farmer and the man who lives in the small country town. The more isolated the communities the greater appears to be the need for contact with the rest of the world by means of radio.

In the early experiments with radio broadcasting of news and market reports, the radio telegraph was employed with the expectation that the amateur radio telegraph operators would become the news centers of the communities and that by receiving the news of the world by radio telegraph together with the reports on agricultural commodities, they would serve the communities by putting this information at the disposal of the people who were interested through the means of mimeographed bulletins and by telephone and through and by the help of the local newspapers. This assumption, however, proved not to be well founded, for the radio amateurs did not seem disposed to tie themselves down to a regular schedule of service

which did not hold out any satisfactory remuneration. Furthermore, this sort of an arrangement became unnecessary when radio telephone broadcasting was inaugurated, for it was then possible for each individual to secure the news, entertainment, and reports for himself, with no greater effort than the installation of radio receiving equipment with which he could tune in the broadcasting stations.

The development of the broadcasting of crop and market reports has opened up a very wide field for the further dissemination of the kind of information which the farmer has needed so long in the conduct of his business. It might be said that the farmer had access to the newspapers and the correspondence of firms with whom he dealt which would bring him market reports and information regarding the sale of his commodities, but these have proved inadequate in a great many instances and have not met the farmer's needs. There are a great many farmers in the live stock producing territory close to the large Mid-Western markets to whom the advent of this new method of market report dissemination has meant a great deal. Outside of the direct benefit which getting the information has meant, radio, because of its newness and novelty as a means of securing information, has stimulated an interest on the part of many farmers to have more complete and accurate information regarding the business end of their industry.

DEVELOPMENT OF THE RADIO MARKET NEWS SERVICE

The Radio Market News Service was begun experimentally on December 15, 1920, and has had a very rapid growth since that time. Crop and market news compiled by the Federal Bureau is being distributed not only by the Federal Bureau but by many

other agencies who are cooperating in its distribution. Many of these local agencies are State Bureaus and Departments of Markets that have facilities for collecting local marketing information which they distribute in their own communities, in addition to the information from national production areas and markets of national importance. The experimental Market News Service which was inaugurated on December 15, 1920, consisted of a single report sent out by radio telegraph at 5:00 p.m. each day from the radio station of the Bureau of Standards of the U. S. Department of Commerce. This plan was carried on for about four months and proved conclusively the practicability of disseminating information in that way. During this experiment a large number of radio amateurs cooperated with the Bureau in copying the reports which were broadcast.

Following this initial experiment the then Bureau of Markets secured the cooperation of the Air Mail Radio Service of the Post Office Department and arranged for the broadcasting of the reports from a number of the radio stations operated by the Air Mail Service which extended in a chain from East to West across the country. Several of these Air Mail Radio Stations were located at points on the leased wire system of the Federal Bureau and at these points the crop and market reports were furnished to the operators of the radio station for broadcasting. Other radio stations in the transcontinental chain of the Air Mail Service relayed the market reports, and thus a band of territory approximately 200 miles wide stretching from East to West across the country was supplied with daily market information by radio telegraph. In this case also the radio amateurs were called on to help in the reception and further distribution of the reports and for a time they cooperated quite

generally with the Bureau and proved that this service could be maintained on a national basis. Owing to the fact, however, that there was no means for compensating these operators they could not be expected to continue copying the reports and distributing them when it meant tying themselves down to a routine schedule. This arrangement, however, with the Post Office Department continued until March of 1923.

Radio telephone broadcasting was being experimented with by a great many people during the year 1921 and tentative arrangements were made with three of these experimental stations to include market reports on their programs. These stations were the University of Minnesota, Minneapolis, Minn., The Westinghouse Electric & Mfg. Company, at East Pittsburgh, Pa., and the St. Louis University, St. Louis, Mo. The first listeners-in on radio telephone broadcasts were the radio amateurs whose radio receiving equipment was just as capable of getting the radio telephone broadcast as in receiving the radio telegraph messages. The friends of these amateurs who were given an opportunity to listen to the radio telephone broadcasting, which in its early stages consisted of phonograph music and the reading of news items and in the few instances which we have enumerated of the broadcasting of market reports, very soon realized the possibilities which radio telephone broadcasting held forth, and many of them with the help of their amateur friends installed equipment to intercept the few broadcasts which at that time were being given out. From this very small beginning the present radio broadcasting situation has developed and the disseminating of market reports has kept pace with the rise of broadcasting, so that at the present time crop and market reports are being broadcast by enough broadcasting stations to cover practically the entire Eastern half

of the United States. The only reason why all of the territory is not covered is due to the fact that there have been no facilities for placing the market reports in the hands of scattered stations in the Western States. This condition will be corrected to a very large extent by the extension of the leased wire system of the Federal Bureau from its former Western terminus at Kansas City to San Francisco.

It will probably never be possible for the Market News Service of the Government to have representatives at every place where a broadcasting station is located, so that there will always be sections of the country to which the crop and market reports will have to be sent for further broadcasting by some other means than the leased wire of the Federal Bureau. Recently experiments have been made with the dissemination of market reports by high power radio telegraph using such stations of the Government operated by the Navy Department located at Washington, D. C. (Arlington, Va.), Chicago, Illinois (Great Lakes, Ill.), New Orleans, La., and San Francisco, Calif. These stations broadcast the market reports by radio telegraph, using powerful sending equipment on long wave lengths. The reception of these radio telegraph broadcasts at points not served by the leased wire system of the Federal Bureau has proved entirely satisfactory. By this means it is hoped to cover these sections of the country with crop and market reports from the Department of Agriculture and have them received by competent operators, translated out of the radio telegraph code into plain English, and re-broadcast by radio telephone for the benefit of the local communities. Such a system will undoubtedly prove very efficient in giving wide distribution to the Government's crop and market reports.

One of the functions of the Radio Market News

Service of the Bureau of Agricultural Economics is to arrange programs and schedules of crop and market reports for the various broadcasting stations which cooperate with the Federal Bureau in the distribution of marketing information. Broadcasting stations have been unable to make any charge for the reports which they broadcast and the Government has seen no way in which it could reimburse them for the services which they have rendered in disseminating information.

FORMS FOR RECORDING MARKET REPORTS

It is a difficult thing to put a market report into a form that will fully satisfy every "listener-in." Some would prefer to have the markets in a conversational paragraph style, while others want barely the essential classes or grades of the commodities and the prices. To combine these two ideas has been the result of several months' study of the efforts of several agencies to make forms that would meet general requirements. Forms for Live Stock and Meats reports, Fruits and Vegetables, Dairy Products, Cotton, Grain, Hay and Feed have been perfected and are being used for the broadcasting of the daily or periodical reports. Farmers, shippers, dealers and others having these forms can copy the essential information about almost any product in which they are interested. The schedules of all stations handling weather, crop and market reports are published in pamphlet form and are also on the radio page of most newspapers.

COOPERATION WITH STATES

It is logical that State and Federal Marketing Agencies should cooperate to make their combined ef-

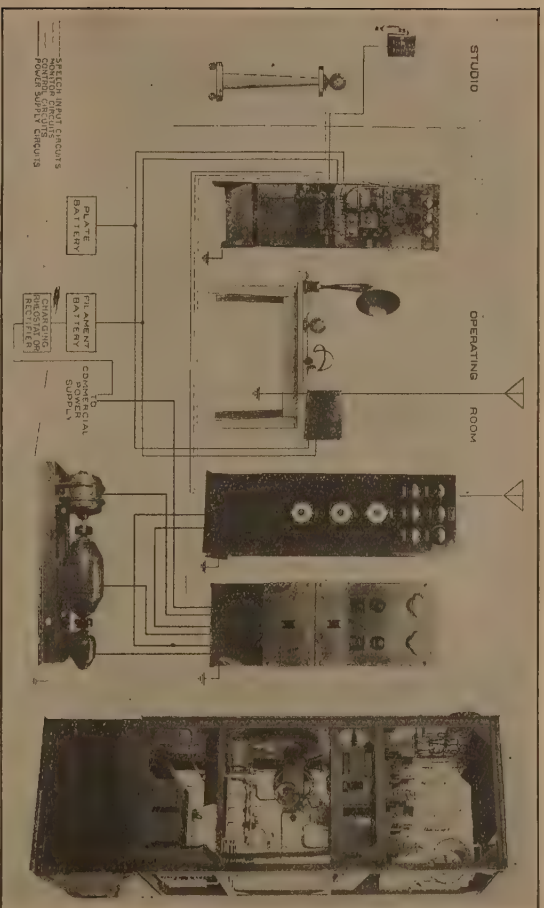
forts of the greatest possible benefit to the producers, dealers and consumers. In the handling of the market news work by radio the State Marketing Bureaus are cooperating to the fullest extent. In some States this work is centered in the Extension Service of the Agricultural Colleges. For example, the Alabama, South Carolina, Iowa and Nevada Extension Services have developed plans for radio broadcasting of reports which the information from the market centers usually originates in the Federal Bureau and its distribution is effected locally by the State agency.

Cooperative agreements covering such market news plans have been entered into by the Federal Bureau and a large number of State Bureaus. The State Marketing Agencies that have made installations of radio broadcasting equipment or have arranged for broadcasting by privately owned stations are:

Alabama Markets Division, California Division of Markets, Connecticut State Board of Agriculture, Delaware Bureau of Markets, Florida Marketing Bureau, Massachusetts Division of Markets, Michigan Division of Markets, Minnesota Bureau of Markets, Missouri State Marketing Bureau, New Jersey, New York, North Carolina, Ohio Division of Markets, Pennsylvania Bureau of Markets, South Carolina Division of Markets, Texas Division of Markets, Iowa State College Extension Service, Wisconsin Department of Markets.

WEATHER BULLETINS BY RADIO TELEGRAPH

Ever since 1913 various naval stations have been broadcasting daily weather bulletins, consisting of code letters and figures showing barometric pressures, wind direction and force, as well as special forecasts of winds. Storm and hurricane warnings are in-



At the transmitting end of radio broadcasting: Complete radio telephone installation, shown in diagrammatic manner. At the right is a side view of the radio telephone transmitter unit, with the vacuum tubes on the top shelf and the other equipment on the shelves below.

cluded whenever issued. These weather bulletins are intended for mariners primarily, and are of little if any interest to the public at large. Furthermore, these bulletins are sent out in code, and therefore require the services of a skilled operator to interpret them correctly. However, further on, while dealing with time signals, we shall deal with these weather bulletins.

The act of Congress creating the Weather Bureau contains the expression, "for the benefit of *agriculture*, commerce, and navigation." Until recent years it was not possible to extend the benefits of the service effectively to agricultural interests, because a large proportion of the farmers could not be promptly supplied with weather forecasts and warnings of cold waves, heavy snows, frosts, etc., by ordinary means of dissemination. Extension of telephone lines into rural communities overcame a part of this difficulty, but large numbers of them could not be served thereby.

The Weather Bureau recognized the possibilities of radio in reaching agricultural interests and it began the dissemination of forecasts by this means as early as 1914. In January of that year arrangements were made for the broadcasting of forecasts by a station operated by the University of North Dakota, and nine amateur operators in that State received the forecasts in this way and made local distribution of them. In June, 1915, similar arrangements were made at Illiopolis, Ill.; Rock Island, Ill.; and Springfield, Ill. Sixteen amateurs, owning receiving sets, were known to obtain and distribute the forecasts.

On February 15, 1921, broadcasts of forecasts by radio stations operated by the Post Office Department in connection with its air mail service at Omaha, Nebr., and North Platte, Nebr., were begun, and a little later from its stations at Washington, D. C.; Bellefonte,

Pa.; St. Louis, Mo.; Cheyenne, Wyo.; Rock Springs, Wyo.; and Salt Lake City, Utah. The service from St. Louis and Bellefonte was in operation only a few months.

The distribution of forecasts by radio telegraphy to interior points served a valuable purpose, but it was of limited use to farmers, because few of them could take the time required to learn the telegraph code, and on that account they did not feel justified in installing receiving apparatus. However, the marvelous developments in radio telephony during the past year or two changed the situation, and the Weather Bureau has kept abreast of these developments.

Broadcasting twice daily, at 10 a. m. and p. m., by radio telegraphy from the Arlington naval radio station of weather forecasts for each of the States comprised in the Washington forecast district, and on Wednesdays (April to October, inclusive) a summary of weather conditions as they affected crops during the preceding week, was inaugurated June 26, 1922. Similar services for the States in the Chicago, San Francisco, and New Orleans district were begun June 20, 1922, August 23, 1922, and January 1, 1923, respectively.

RADIOPHONE WEATHER BROADCASTS

The first systematic radiophone broadcasts of forecasts were made from the station operated by the University of Wisconsin beginning with January 3, 1921. Prior to that date and since October 1, 1916, broadcasts had been made therefrom by radiotelegraph. The next radiophone forecast distribution service was inaugurated on April 26, 1921, by the St. Louis (Mo.) University. This was the first station to disseminate river forecasts by this means.

On July 1, 1921, twelve radiophone stations in seven States were broadcasting weather information, daily forecasts, river forecasts, crop information, cold-wave, frost, and other warnings. Since that time the work has been rapidly extended, and at the present time 118 radio telephone stations in 40 States are engaged.

Practically all of the State forecast radio distribution work is conducted in cooperation with plants owned by individuals and commercial organizations, and at very little expense to the Weather Bureau. The forecasts and warnings are supplied them, as a rule, by telephone from field stations.

No broadcasting of weather reports and forecasts by radiophone were made by the Navy Department until February 15, 1923, on which date such service began from the Arlington station on 435 meters wave length. This service consists of the broadcasting, twice daily, at between 10:05 and 10:20 a. m. and p. m., of the forecasts for each of the States comprised in the Washington forecast district (all States east of the Mississippi River except Michigan, Illinois, and Indiana) and a general forecast for the district. Special warnings of cold waves, frosts, heavy snows, etc., issued in the afternoon and not included in the regular morning and evening broadcast, are disseminated between 3:45 and 4 p. m. Distant control operation is a feature of this service. The Weather Bureau office is connected by telephone with the radio operating room of the Navy Department, and the forecasts are announced from the forecast room of the Weather Bureau.

At a meeting of the Inter-departmental Advisory Committee on Governmental Radio Broadcasting held on February 2, 1923, it was decided to transfer all broadcasting done by the Post Office Department for the Department of Agriculture, including the Weather

Bureau, to the Navy Department. The Arlington radiophone service was inaugurated in accordance with this program. This affects the service performed by the Post Office radio stations at Washington, D. C.; Omaha, Nebr.; North Platte, Nebr.; Rock Springs, Wyo.; and Salt Lake City, Utah, and broadcasts of weather reports and forecasts from Washington were discontinued February 15, and from the other stations of the Post Office Department on March 1, 1923.

TIME SIGNALS AND STORM WARNINGS

One of the important radio features not usually appreciated by the radio listener-in, because it is in the dot-dash language, is the broadcasting of time signals and weather bulletins by the high power naval station at Arlington, Va. The time signals and weather bulletins are sent out twice daily on a wavelength of 2655 meters, at 11.55 a. m. and 9.55 p. m. The signals begin at these times and the final dash is sent at 12 noon and 10 p. m. These signals are astronomically correct for the meridian of 75 degrees west of Greenwich.

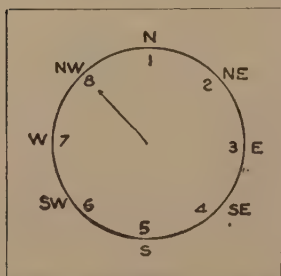
The signals are sent out as follows: Beginning at 11.55 a. m. or 9.55 p. m. a dot is sent every second for the first thirty seconds, then one second is skipped, and beginning with the thirty-first second to the fifty-fifth second the dots are again sent, one each second. The last five seconds of the first minute are skipped, and the signals begin again at exactly the beginning of the fifty-sixth minute. The same schedule is maintained through the fifty-seventh and fifty-eighth minutes right through until the fiftieth second of the last minute is attained. Then comes a silence or blank for ten seconds, and the next dash is exactly 12 o'clock noon or 10 o'clock in the evening, as the case may be.

The general scheme of the time signals is perhaps made clearer by studying the chart on facing page. This time is absolutely accurate and is employed by ships at sea for the setting of chronometers, and by progressive jewelers and others desiring an accurate time service. The signals are transmitted at Arlington, to be sure, but the dots originate in a master clock at the Naval Observatory.

No sooner are the time signals over than the Arlington station sends out the weather bulletin in code—a code, however, which is quite simple to understand. A weather bulletin, as sent out by Arlington, runs as follows:

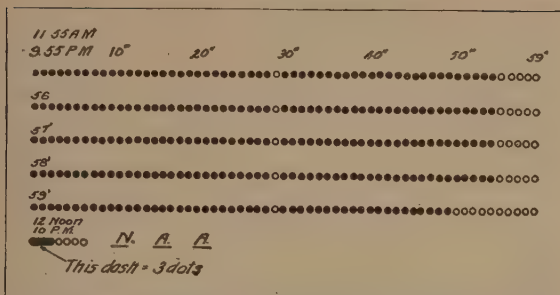
QST de NAA, USWB, S01081—T02261—
DB0251 — H00844 — C01261 — K00441—
P1242.

All of which means, when reduced to plain English, that the letters stand for K—Key West, Fla.; S—Sidney, Nova Scotia; T—Nantucket, R. I.; DB—Delaware Breakwater; H—Cape Hatteras, N. C.; C—Charleston, S. C.; P—Pensacola, Fla.; B—Bermuda. The first



How numerals are used to indicate the points of the compass in connection with the direction of wind numerals used in the Arlington weather bulletins.

three figures following the letters are barometer readings of various places. Taking the first set of figures sent out, S01081, the figures 010 represent the barometer reading of 30.10 inches, and the next figure represents the direction of the wind, which happens to be NW in this case, since the numerals begin with 1 for North, 2 for NE, 3 for E, 4 for SE, and so on, as shown in the accompanying dia-



Diagrammatic explanation of the official Navy time signals as sent out by the Arlington station. These signals are re-transmitted by certain broadcasting stations. Each black dot represents a transmitted dot, while the white dots represent spaces or silent intervals. The time signals start five minutes before 12 o'clock noon and ten o'clock P. M. and follow the schedule here depicted, terminating with a dash on the hour, followed by a four dot space and the call letters N A A.

gram, reading around the compass in the same direction as travel the hands of a clock. The last numeral means the velocity of the wind, and the following table gives the figures and their values in statute miles (1.15 nautical miles) per hour:

0—Calm	0 to 3 miles per hour
1—Light air	8 miles per hour
2—Light breezes	13 miles per hour
3—Gentle breezes ...	18 miles per hour
4—Moderate breezes .	23 miles per hour
5—Fresh breezes	28 miles per hour
6—Strong breezes ..	34 miles per hour
7—Moderate gale ...	40 miles per hour
8—Fresh gale	48 miles per hour
9—Strong gale	56 miles per hour
10—Whole gale	65 miles per hour
11—Storm	75 miles per hour
12—Hurricane	90 miles per hour

Now, therefore, take the code signal K00441. The K, it will be noted, stands for Key West; the figure 004 states that the barometer stands at 30.04 inches; the next figure indicates that the direction of the wind is South East, and the last figure, 1, represents the velocity of the wind, which in this instance is light air, or a breeze having a velocity of only eight miles an hour.

The Arlington time signals and weather bulletins are sent on a wave length of 2655 meters. The call letters of this station are N A A, which are signed immediately after the final dash in the time signals. Fortunately, the weather bulletins are sent at a slow, even speed, so that a person with only a slight training in the telegraph code can copy down the letters and figures. It is well to mention here that the bulletins are sent out by automatic transmitter, so that the dots and dashes are perfectly formed.

Certain radio-phone broadcasting stations give out the time signals by radio-phone. This is accomplished by receiving the time signals from Arlington on a long-range receiving set, and then amplifying these signals until they are sufficiently loud in a telephone receiver which is held up to the transmitter microphone for retransmission via the radio-phone. In this manner the persons in the vicinity of the radio-phone broadcasting station can receive the time signals without having to tune up to the long wave length of the Arlington stations. Furthermore, the radio-phone broadcasting stations receive the weather bulletins and broadcast them in plain English, which requires, of course, absolutely no knowledge of the telegraph code.

Aside from the Arlington station, various naval stations broadcast time signals, weather bulletins and press reports, in code. Thus Balboa, C. Z., broadcasts time, press and weather; Bar Harbor, Me., press;



Group of young men learning the telegraph code. A telegraph key, high-pitch buzzer, and a couple of dry cells serve to simulate radio telegraph signals in the telephone receivers worn by the students and the instructor. The instructor sends out the signals which are jotted down by the students. At first the messages are simple and are sent at a slow rate of speed, but by degrees the speed is increased and the messages become more involved.

Boston, Mass., weather; Brownsville, Texas, weather; Cavite, P. I., press, time and weather; Charleston, S. C., weather; Colon, C. Z., time and weather; Dutch Harbor, Alaska, weather; Eureka, Calif., weather and time; Great Lakes, Ill., weather and time; Honolulu, T. H., time and weather; Inglewood, Calif., weather; Jupiter, Fla., weather; Key West, Fla., weather and time; New Orleans, La., weather and time; New York, N. Y., weather; Norfolk, Va., weather; North Head, Wash., weather and time; Pensacola, Fla., weather; Philadelphia, Pa., weather; Portland, Me., weather; Puget Sound, Wash., weather; San Diego, Calif., press and time; San Francisco, time, press and weather; San Juan, P. R., weather; Savannah, Ga., weather; St. Augustine, Fla., weather; Tutuila, Samoa, weather; Washington, D. C. (Annapolis) time and press.

CHAPTER XII.

HOOK-UPS—WORKING PLANS FOR THE RADIO ENTHUSIAST

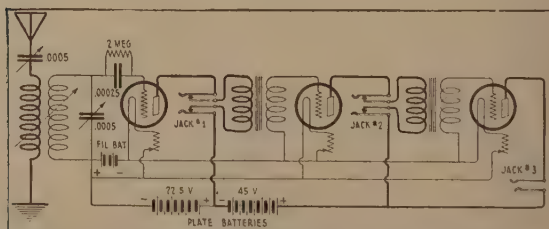
AND now we come to that part of our book that is especially intended for those readers who prefer to build their own sets, not only for the economies that may be effected thereby, but more particularly for the sheer enjoyment of doing the work themselves.

In former editions of this book we told how to build several simple receiving sets, among them a very elementary crystal receiver and a vacuum tube receiver. However, at this time, when such parts as variometers, vario-couplers, variable condensers, sockets, jacks, rheostats and so on are available at prices well within the reach of all, it no longer pays to make these simple parts. Indeed, radio construction is strictly a matter of assembling bought parts. The skill starts with the selection of the proper design, followed by the purchase of good parts. In the long run it does not pay to buy the cheapest parts on the market, for they are generally inferior and lessen or even ruin the efficiency of the completed receiver. The parts must be assembled with care, not only from the mechanical con-

siderations but also from the electrical. The wiring should be carefully done with the copper wire or bus bars sold by radio dealers. Note the neatness with which the parts and the wiring have been arranged in the receiver shown on the facing page. Such work is bound to give better results than a set thrown together in a haphazard manner, with the parts poorly distributed and with the wiring virtually in a tangle.

HOO-K-UPS—FROM SIMPLE REGENERATIVE TO SUPER-HETERODYNE

Of hook-ups, or radio wiring diagrams, there is no end. Every issue of the numerous radio magazines, every radio supplement of the large metropolitan newspaper, every radio enthusiast you meet, confronts you with a brand new hook-up which is claimed to be the last word and to revolutionize the reception of radio programs. It will always be thus; for, after all, radio is just that sort of thing. A signal may be intercepted in so many different ways that there must



This diagram is intended to show the use of jacks in a radio circuit. For the sake of simplicity the jacks are not indicated in the usual wiring diagram or hook-up. The jack, which is the companion instrument to the plug, permits of introducing a pair of telephones, loud-speaker, or other device in a given part of the circuit.



Working parts of a regenerative receiver, showing the manner in which the components are mounted on the shielded panel and on a shelf. Note the neat rigid wiring, which characterizes good radio craftsmanship.

necessarily be no end to the combinations worked out for receivers.

In the pages that follow, the author has endeavored to assemble a few hook-ups covering a wide range of requirements. Starting with the single tube non-regenerative receiver, these hook-ups cover regenerative receivers, super-regenerative receivers, superdyne receivers, and finally the super-heterodyne. The radio-frequency family of receivers, including the neutrodyne type, has been dealt with in the chapter dealing with that subject. Audio-frequency amplifiers have been dealt with in their respective chapter. There is no attempt made here, with our space limitations, to cover the constructional details at length. The diagrams are given, together with concise specifications for each receiver.

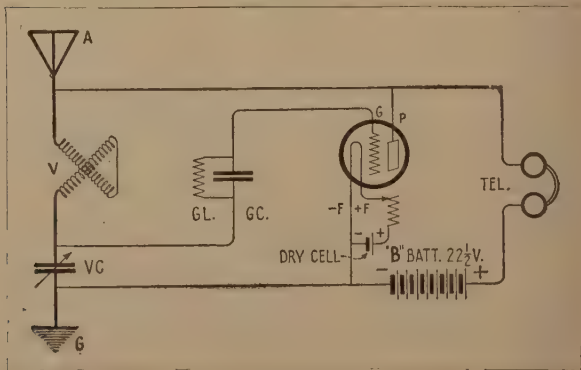
The author strongly advocates the radio enthusiast to buy the so-called kit or complete parts for such circuits as the super-heterodyne, ultradyne, neutrodyne, and other special circuits. These kits are accompanied by complete instructions.

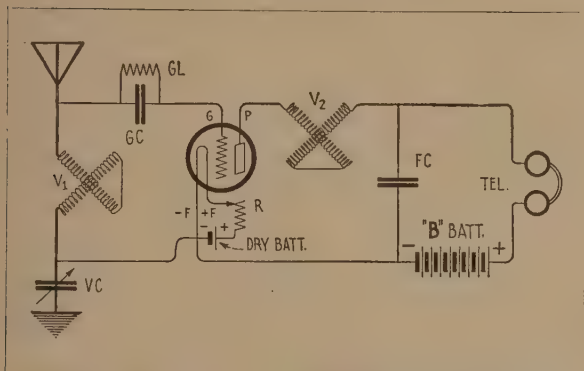
SIMPLE SINGLE-TUBE OR "FLIVVER" RECEIVER

For the radio enthusiast who desires an inexpensive receiver, there are numerous single-tube hook-ups for the so-called "flivver" receivers. Here is a typical "flivver" arrangement which, with a 100-foot antenna, will receive from the usual broadcasting stations over a distance of 1,000 miles. For comfortable reception at such distance, a one-stage audio-frequency amplifier should be employed.

This receiver consists of a single variometer V , and a variable condenser of the 43-plate size, VC , for the tuning elements. If the builder prefers, a No. 50 duo-lateral coil—one of the several types of compact inductance coils on the market—may be used in place of the variometer. The variometer, however, makes for much finer tuning and is preferable in locations where there is considerable interference.

Then there is the usual grid leak (2 megohms) and grid condenser (.00025 micro-farad), GL and GC , the tube with the binding posts of the socket indicated, the rheostat, a dry battery or storage battery, the "B" battery, and the telephone head-set.





TWO-CIRCUIT TWO-VARIOMETER REGENERATIVE RECEIVER

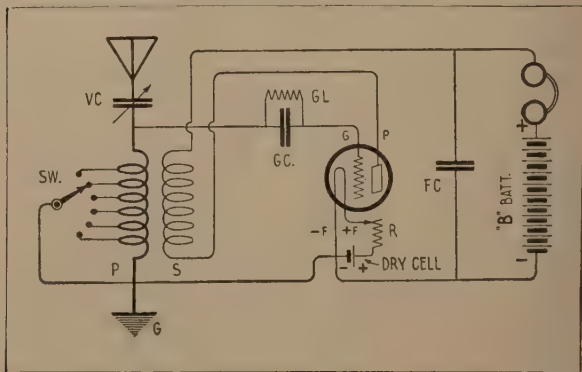
Somewhat more ambitious and certainly more satisfactory for tuning and for volume is the receiver shown on this page. It makes use of a variometer V_1 and a variable condenser VC of the 43-plate size, for tuning the antenna-ground or wave-intercepting system, and a second variometer V_2 for tuning the plate circuit for the purpose of obtaining regenerative amplification. A .00025 micro-farad grid condenser GC and 2 megohm grid leak GL are employed as indicated. The circuit is completed with a vacuum tube and socket with the terminal connections indicated, a rheostat, an "A" battery and "B" battery, a pair of telephone receivers, and a fixed condenser of .001 micro-farad capacity, FC , which may or may not be required, according to circumstances. Often the capacity of the twin conductors in the telephone cord will be found sufficient.

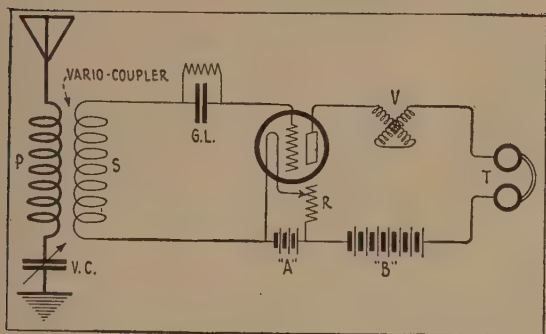
This type of receiving set is simple to adjust and will operate over a range of 1,000 miles under the usual normal conditions. It is not a "tricky" set and is therefore more satisfactory than the simpler types in which a single tuning member is made to perform a number of functions.

SIMPLE REGENERATIVE RECEIVER WITH TICKLER COIL ARRANGEMENT

The regenerative receiver shown in the accompanying diagram has been the basis for many so-called "circuits" parading under as many assumed names. As a single-tube receiver, it is highly efficient, but it has the one drawback of strong radiation possibilities in the hands of the average beginner. That is to say, if the regenerative feature is not handled with the greatest care, the set oscillates and sends out a powerful wave which interferes with nearby receivers tuned to the same wave.

This circuit makes use of either two separate coils, such as the compact inductances of the duo-lateral or honeycomb type for the *P* and *S* coils, or a standard vario-coupler with the rotor used as the tickler coil *S*. A 43-plate variable condenser *VC* is used to tune the antenna-ground circuit. There is the usual grid leak *GL* and grid condenser *GC*, the dry cell or storage battery for the tube filament, the rheostat, the telephones, the "B" battery, and a fixed condenser of .001 micro-farad capacity, which may or may not be required according to conditions. Tuning is accomplished by means of the variable condenser and the coupling between coils *S* and *P*. Both tuning controls should be operated simultaneously, so that the tube is kept just below the oscillating point, as explained in Chapter X.





A SHARPLY TUNED REGENERATIVE RECEIVER

The receiver shown on the facing page is generally built with a vario-coupler, which, instead of playing the role of coupler between the antenna-ground and the detector circuit, affords a means of regenerative adjustment. However, for the sharpest tuning it is necessary to use the vario-coupler for its intended purpose, hence the accompanying diagram. Here the primary *P* and secondary *S* of the vario-coupler are employed to tighten or loosen the coupling between the wave-intercepting system and the detector circuit, while the regenerative control is of the tuned plate type, with a variometer *V* serving the purpose.

This receiver will be found quite selective, although for best results the detector circuit should also be tuned by the addition of a 23-plate variable condenser across the secondary coil *S*. Fair results are obtained by leaving the secondary circuit untuned, thus simplifying the set and its operation.

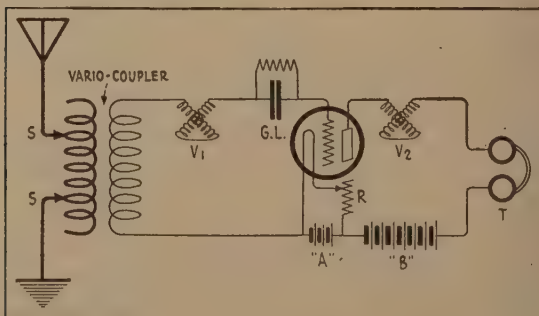
The usual grid leak and grid condenser *GL* are called for, as well as the "A" battery for the tube filament, the rheostat *R*, the "B" battery, and the head-set.

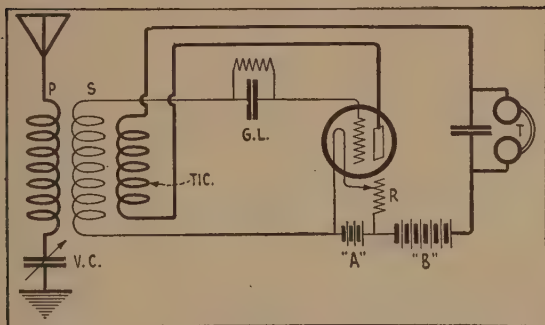
TWO-VARIOMETER AND VARIO-COUPLER
REGENERATIVE SET

Until the advent of the present line of radio-frequency amplifier sets, the most popular receiver was the two-variometer and vario-coupler regenerative type, shown in the accompanying diagram. Here we have a vario-coupler for coupling the wave-intercepting and the detector circuits, and a variometer *V-1* for tuning the secondary or detector circuit. The regenerative action is obtained by means of a second variometer, *V-2*, which tunes the plate circuit.

This set tunes exceedingly sharply and has made itself famous by its long-distance records. However, it is quite difficult to operate and the best results of which it is capable are obtained only in the hands of the experienced radio man. It is ideal when employed with ear-phones, but for loud-speaker operation the simpler circuits, particularly that on page 330, known as the single-circuit regenerative, have a greater output.

Here we have a vario-coupler, preferably with two switches to cut in any desired number of primary turns for tuning the wave-intercepting system. *V-1* and *V-2* are the variometers for tuning the detector circuit and controlling regeneration. *GL* is the usual grid leak and condenser. There are the "A" and "B" batteries, rheostat *R*, and telephone receivers *T*.





THE THREE-COIL REGENERATIVE RECEIVER

Another set which was highly popular before the advent of the radio-frequency amplifier sets and which is still pressed into service when more elaborate circuits prove disappointing, is the three-coil regenerative arrangement shown in this diagram.

Use is made of three compact inductance coils of the duo-lateral or honeycomb type. The proper sized coils should be used, and this data can be secured from any radio dealer or from the literature of the coil manufacturers. Indeed, the principal feature of this arrangement, aside from its simplicity and inexpensiveness, is that it can be immediately altered to receive any range of wave lengths. Thus the operator can shift from the radio broadcast wave lengths to the long-wave transatlantic signals, merely by changing the coils which are provided with interchangeable mountings.

The wave-intercepting system has one coil *P* in series with a 23- or 43-plate variable condenser. Then there is a secondary coil *S* for the detector circuit. While this circuit need not necessarily be tuned, it is preferable to place a 23-plate variable condenser across it. Then there is a third coil, smaller than the other two, known as the tickler, which is the regenerative control. The set is completed with grid-leak and grid condenser *GL*, "A" and "B" batteries, rheostat *R*, .001 fixed condenser which is optional, and telephone receivers *T*.

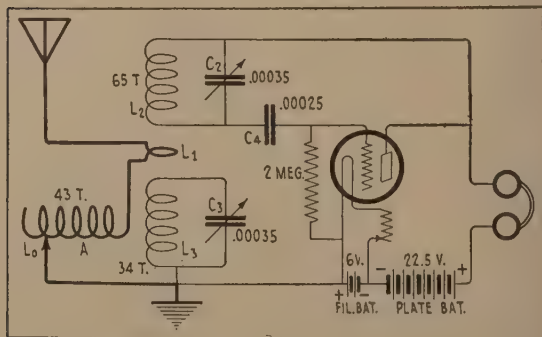
THE COCKADAY FOUR-CIRCUIT RECEIVER

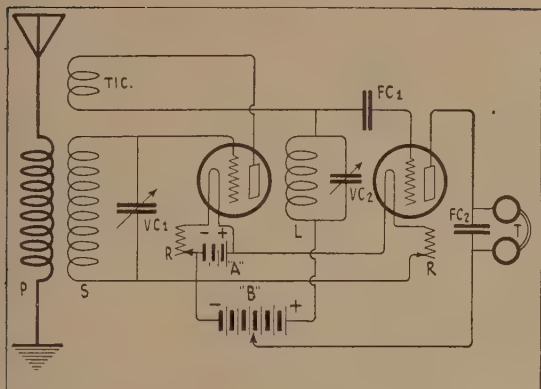
We now come to the more ambitious types of regenerative receivers, of which the Cockaday four-circuit receiver is a well-known example. This circuit is a development of the DeForest ultra-audio, which, some ten years ago, first disclosed the remarkable possibilities of the vacuum tube as a super-sensitive radio detector. The Cockaday circuit is highly selective and sensitive, but it is really too critical for the beginner.

The main feature of the Cockaday circuit is the arrangement of four coils. Fortunately, these four coils, mounted in one unit, may be purchased and it will not pay the radio builder to make his own. *L-0* is the antenna loading coil, consisting of 43 turns, while *L-1* is the primary winding, consisting of a single turn of heavy copper wire. *L-2* and *L-3* are intended for the detector circuit and the regenerative control. Regeneration is accomplished by means of inductance coil *L-3* and condenser *C-3*.

The Cockaday circuit has its adherents, although like most of the other regenerative circuits it has had to make way for the simpler radio-frequency circuits and reflex receivers.

The turns for the various inductances, and the values for the condensers and the grid leak, are indicated in the diagram. It will be noted that the windings *L-2*, *L-3* and *L-1* are wound on the same support, while *L-0* is on a separate support mounted at right-angles to the other coils.





THE EXCELLENT BUT FUSSY SUPERDYNE RECEIVER

Among the present-day receivers is the superdyne, which gives excellent results after the adjustments have been mastered. The superdyne has made numerous long-distance records in the hands of skilled operators.

The superdyne, like the neutrodyne, acmedyne, super-heterodyne and other special circuits, is strictly a "kit" proposition. That is to say, the builder should purchase a superdyne kit from a reliable manufacturer, rather than endeavor to wind his own coils and buy various odds and ends for the purpose of simulating a superdyne receiver. Exclusive of the audio-frequency amplifier, the parts required are a superdyne coupler, represented by the primary *P* and secondary *S* coils, the superdyne coil *L* with its 11-plate variable condenser *VC-2*, the secondary condenser *VC-1*, the tickler coil *Tic*, two rheostats *R*, two sockets, one grid leak resistance of 2 megohms in the grid lead, one .001 microfarad grid condenser *FC-1*, one fixed condenser .00025 microfarad *FC-2*, and the usual batteries and telephone receivers.

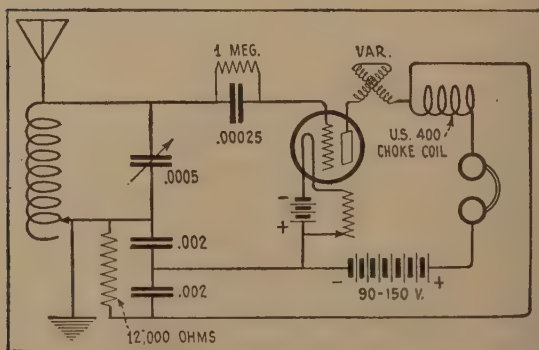
The superdyne is a fussy set to build and a fussy set to operate. If this circuit is desired, buy a reliable superdyne kit, build according to directions, and tune according to directions.

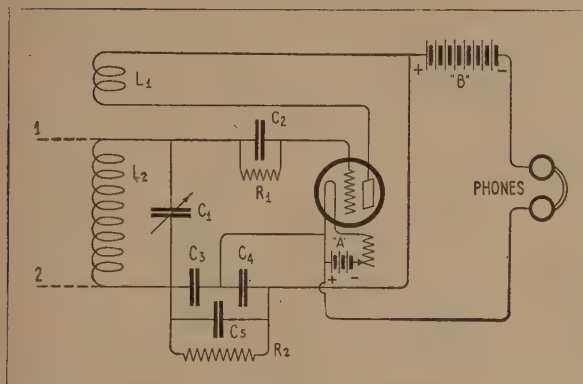
A TYPICAL SUPER-REGENERATIVE RECEIVER

The desire to squeeze more and more volume out of a single vacuum tube has caused no end of super-regenerative receivers. While it is true that some of these circuits when properly built produce remarkable volume from a single tube, it is equally true that they are very critical and difficult to manage. As a general rule these circuits are not recommended to the beginner.

Here we have the Bishop super-regenerative receiver, which may be considered typical of this group. The inductance in the antenna-ground circuit, in this instance, consists of 75 turns of No. 22 double cotton covered wire wound on a 3-inch tube with taps for every five turns. The variometer is of the standard type, and is connected in circuit with a compact inductance coil of the duo-lateral or honeycomb type. The values for the various units are indicated in the diagram, hence no further data need be given here.

In some respects this circuit is similar to the Flewelling super-regenerative receiver, which is presented on the facing page.

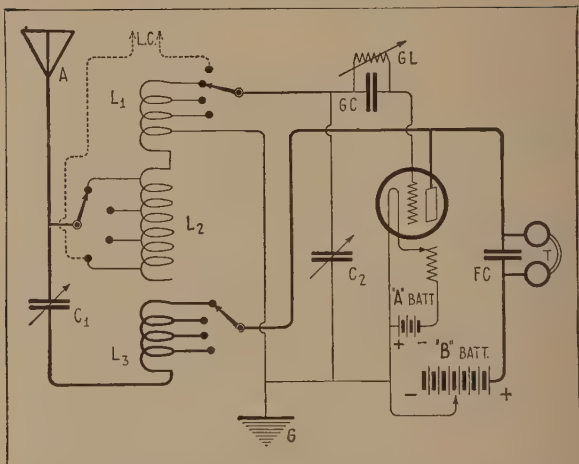




THE FLEWELLING SUPER-REGENERATIVE RECEIVER

Radio authorities are agreed that the Flewelling circuit is the simplest possible arrangement for obtaining super-regenerative results with a single tube. The Flewelling circuit gets along without the large inductances such as are found in the Armstrong circuits, and replaces these with fixed capacities which are not at all critical as to values. The inductance of the telephone receivers has been employed where an inductance is required in the plate circuit.

The components are *L-1*, a 75-turn duo-lateral coil; *L-2*, a 50-turn coil; *C-3*, *C-4* and *C-5* are fixed condensers each approximately .006 microfarad, not critical. *R-1* is a grid leak, 1 to 1½ megohms, critical. *R-2* is of ½ megohm value. *C-1* is a variable condenser of .0005 microfarad. *C-2* is a grid condenser of .00025 microfarad capacity. The leads indicated by dotted lines 1 and 2 are used in various ways, such as with either antenna or ground alone, or one side of a loop connected with 1, leaving 2 free. This circuit is super-sensitive and highly critical.

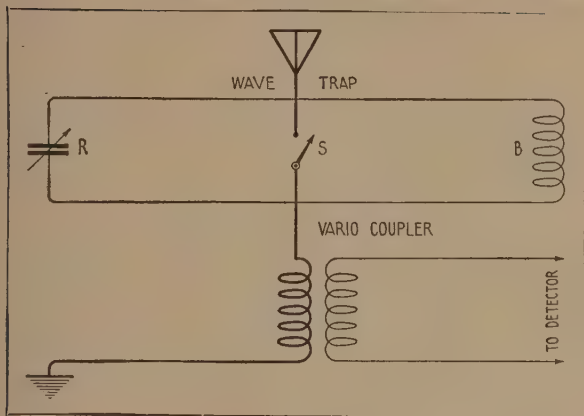


THE REINARTZ SUPER-REGENERATIVE CIRCUIT

Prominent among the trick super-regenerative circuits is the Reinartz receiver, shown herewith. Despite its simplicity, the Reinartz is remarkably efficient.

The main feature of the Reinartz circuit is a special Reinartz spider-web coil, which is available at all first-class radio shops. Here again it does not pay to make such a coil one's self.

The special Reinartz spider-web coil has three windings, *L-1*, *L-2* and *L-3*. Complete directions come with the Reinartz coil, while the taps are labeled to avoid errors in connecting. *C-1* is a 23-plate variable condenser; *C-2* is an 11-plate or 13-plate variable condenser. *GL* is a variable grid leak. *GC* is a .00025 grid condenser. *FC* is a fixed condenser of .001 microfarad, which may or may not be required. Dotted lines and *LC* represent the connections for a loading coil to increase the wave length. *T* represents the telephones.



THE WAVE TRAP—WHAT IT IS AND WHAT IT DOES

There are times when even the best radio receiving set is subject to considerable interference especially from spark transmitters. In such event it is advisable to make use of a wave trap, which is shown herewith. The function of this simple device, which consists of a condenser and an inductance in parallel with one another and in series with the usual tuner and the antenna, is to trap undesired signals and prevent them from reaching the detector.

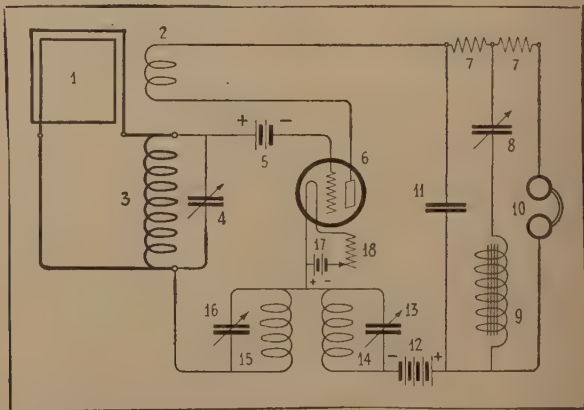
The arrangement shown consists of a variable condenser of .0005 microfarad capacity or about 23-plate size, and a honey-comb or duo-lateral coil of 25 turns. If desired, one can make one's own coil by winding 25 turns of No. 22 double-cotton covered wire on a cardboard tube 3 inches in diameter. *R* represents the condenser, *B* the inductance or coil, *S* a shorting switch to throw out the wave trap when it is not desired.

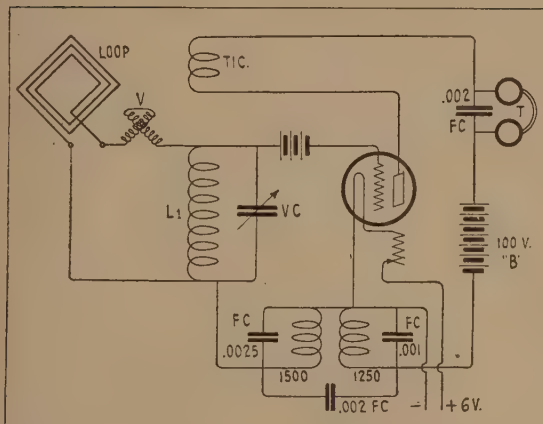
A FLIVVER ARMSTRONG SUPER-REGENERATIVE RECEIVER

Here is a simple single-tube or flivver Armstrong super-regenerative receiver used with a 3-foot loop. A feed-back circuit composed of elements 13, 14, 15 and 16, is adjusted to oscillate at a lower frequency than the incoming signal. The proper phase relations between negative and positive resistances are obtained by adjustment of condensers 13 and 16, and the coupling between coils 14 and 15.

This flivver circuit, as is typical of all such arrangements, is exceedingly fussy to build and to operate with successful results. It is intended more for the radio experimenter.

The elements shown are: 1—Loop antenna, 12 turns on 3-foot frame, wound spirally. 2—Secondary of usual vario-coupler, with twice the usual number of turns. 3—Primary of vario-coupler. 4—Variable condenser, .001 micro-farad. 5—"C" battery, 4 volts maximum. 6—Vacuum tube, "hard" or amplifier type. 7—Resistances of 12,000 ohms each. 8—Variable condenser, .001 micro-farad. 9—Iron core choke coil, 100 millihenries inductance. 10—Telephones. 11—Fixed condenser, .005 micro-farad. 12—"B" battery, 80 volts. 13—Variable condenser .005 micro-farad. 14—Duo-lateral coil, 1,500 turns. 15—Duo-lateral coil, 1,250 turns. 16—Variable condenser, .005 micro-farad. 17—Storage battery, 6 volts or 8 volts, according to tube used. 18—Rheostat.





ANOTHER FLIVVER ARMSTRONG SUPER-REGENERATIVE RECEIVER

Here is another Armstrong single-tube super-regenerative receiver, capable of surprising volume from one tube. The wave-intercepting system is a loop of from 12 to 15 turns on a 3-foot frame. The variometer, *V*, is of the standard type. The variocoupler, indicated by *L-1* and the *Tic.* winding, should have about 80 turns on the primary and 35 to 50 on the secondary. Good variable condensers should be used.

The circuit is more or less explanatory, inasmuch as most of the values are indicated. *VC* is a 43-plate variable condenser.

The resistance of the secondary circuit should be kept as low as possible by making the leads to the detector oscillator tube short. Composition tubing or "spaghetti" should be used to support the windings, and care taken to make the connections and contacts good.

If an aerial is handy, it may be found advantageous to use it until the operation of the set is mastered, after which it is neither helpful nor wise to use an aerial, inasmuch as this set is super-sensitive and is intended primarily for use with a loop. Furthermore, when used with an aerial it will radiate strongly.

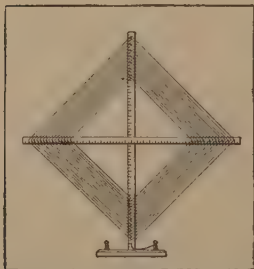
THE SUPER-HETERODYNE RECEIVER

The two circuits which represent the best possibilities for the radio home builder are, in the estimation of the author, the super-heterodyne and the neutrodyne—the former if the use of an antenna is more or less out of the question, and the latter if a simpler set is desired, to be used with an antenna. The ultra-dyne, which is a modification of the super-heterodyne, is, of course, included. So the following pages are devoted to these three popular circuits.

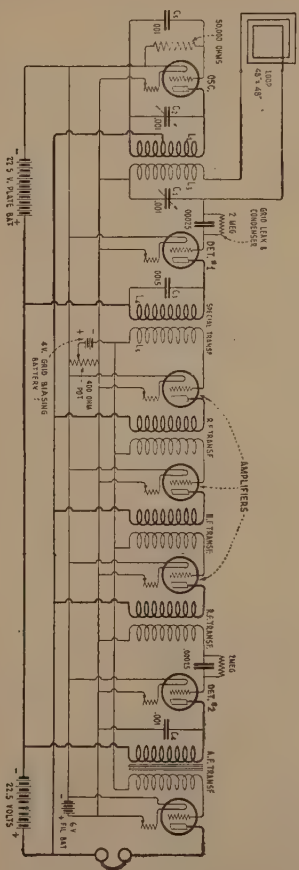
Considerable has already been said in this work regarding the super-heterodyne circuit. It is essentially a radio-frequency amplifier making use of fixed transformer-coupled stages at their greatest efficiency. For this purpose the incoming radio waves are played off against a locally generated wave, and the difference between these two waves or frequencies gives rise to

a beat note effect of the desired wave length. It is the beat note effect, carrying all the variations of the incoming wave, that is passed through the radio-frequency amplifier, which in this instance is called an intermediate-frequency amplifier.

As might well be expected, there are several variations of Major Armstrong's famous super-heterodyne circuit. However, there appears on the facing page a typical super-heterodyne circuit.



Simple spiral type of loop made with two yard sticks, brass brads, and the necessary wire. The turns should be one-half inch apart or more.

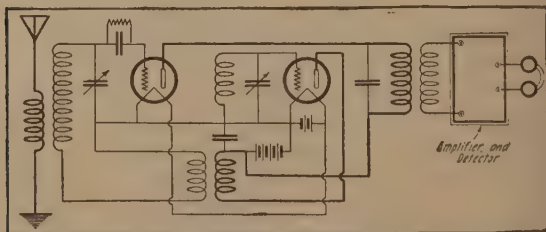


Typical super-heterodyne circuit, with two detector tubes and a separate oscillator. Note that there is no reflexing in this circuit, and that only one stage of audio-frequency amplification is included.

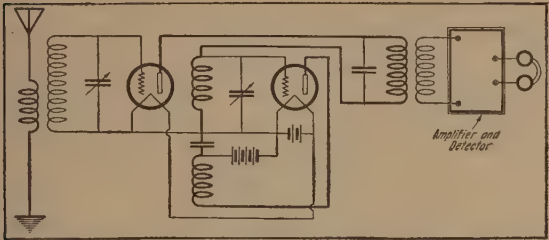
It will be noted that a loop is employed instead of an antenna. Indeed, this super-heterodyne arrangement is so sensitive that the loop consists of ten turns of No. 18 bare or insulated copper wire wound on a frame two feet square, with $\frac{3}{8}$ inch between turns. The sketch on page 242 shows a loop made up of two yardsticks and wire. If desired, a very small antenna and ground connection may be tried for the reception of distant signals.

The intercepted signals are interfered with on their way to the first detector, or detector No. 1, by the locally produced wave set up in the oscillating circuit. The oscillating circuit consists of a "hard" tube called the oscillator, inductances $L-1$ and $L-2$, and variable condenser $C-2$. This condenser, as well as $C-2$, is an ordinary 43-plate instrument. The oscillator coil is made up of three separate windings, $L-1$, $L-2$ and $L-3$. $L-1$ has 22 turns of No. 26 double cotton covered wire, while $L-2$ has 16 turns of the same wire, wound on a $3\frac{1}{2}$ inch tube. $L-3$, on the other hand, has 8 turns of No. 26 double cotton covered wire on a tube 3 inches in diameter, which may be arranged to slide in the larger tube, so as to regulate the coupling.

So much for the oscillator coupling. The oscillating



Arrangement of the oscillator and the first detector in the usual super-heterodyne receiver. Contrast this with ultradyne arrangement on facing page.



Arrangement of the so-called modulation system used with the ultradyne receiver. No pick-up coil and grid condenser are employed and no B' battery is connected with the modulator tube, the plate of which is supplied with high-frequency current from the oscillator.

circuit is tuned by adjusting the variable condenser C-2. The only other tuning control is the condenser C-1, which varies the wave length of the wave-intercepting system. The oscillating circuit is tuned so as to produce the proper local wave length or frequency to set up the proper beat note with any incoming signal desired. The beat note is passed on to the intermediate-frequency amplifier by means of the special transformer indicated after the detector tube. This transformer may consist of a duo-lateral or honeycomb coil with an inductance value of about 6 millihenrys for the primary, and two similar coils connected in series and mounted on either side of the primary coil to form the secondary. A fixed condenser of .0015 microfarad is placed across the primary. The other elements of the circuit are plainly indicated. Attention is called to the radio-frequency transformers, which should be of a good type. The General Radio Company's intermediate-frequency transformers are ideal for this purpose. The Radio Corporation of America UV-1716 transformers are also suited for this

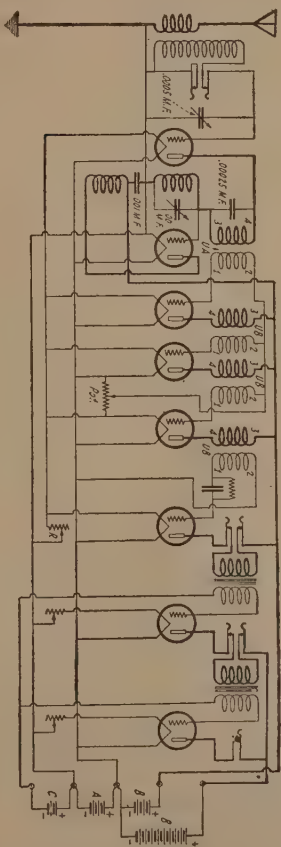
application. Then there are the Remler, Receptrad, Branston and other good makes.

Frankly, the best results with a super-heterodyne receiver are obtained by purchasing a complete kit of reliable make. The author has had excellent results with an assembled Receptrad kit, which, in the complete receiver, consisted of eight tubes. Victor Greiff, designer of the Receptrad apparatus, has written an excellent super-heterodyne manual which accompanies the Receptrad kit or, if preferred, may be purchased separately. This manual will be found to contain much detailed information on the super-heterodyne receiver and its operation.

The Remler super-heterodyne kit, while not so complete as the Receptrad and therefore calling for the addition of considerable nondescript parts, also makes an excellent receiving set. No doubt the same may be said for other reliable makes of kits. In short, the builder of a super-heterodyne had best purchase a reliable kit and build the set only after reading the directions through carefully, and then proceeding step by step. This type of receiver is entirely too fussy to be attempted in a haphazard way and from a miscellaneous collection of irrelevant parts.

THE ULTRADYNE RECEIVER

The ultradyne receiver is a modification of the super-heterodyne, and an entirely different method is used to produce the beats. This method is called the modulation method, and causes the incoming signal to modulate the oscillations produced locally in the same way that the speech and music modulate the carrier wave of a broadcast station. This method, which is a departure from the detector arrangement of the super-heterodyne, is not only more simple but it is claimed to produce greater signal



Typical ultradyne receiving circuit. UA and UB are special transformers or so-called ultraformers which may be bought. In fact, this circuit is essentially a kit set, and should not be attempted from nondescript parts.

strength, which is more noticeable on weak signals. In two diagrams on pages 344 and 345 we indicate the essential differences between the super-heterodyne and the ultradyne circuits, as well as the actual wiring diagram on page 347 for a complete ultradyne receiver.

The oscillator coil and the special transformers, known as ultraformers, are available in a special kit, hence no specific data is necessary here.

THE NEUTRODYNE RECEIVER

In the chapter dealing with radio-frequency amplification, we dealt at some length with the neutrodyne circuit, and presented the hook-up data. The neutrodyne receiver should not be attempted from a miscellaneous collection of irrelevant parts. It is a simple receiver when completed, but it is not so simple to design and construct. The safest procedure is to build such a set from one of the several reliable neutrodyne kits now available, and to follow the directions with great care as regards the adjustment of the neutralizing condensers or neutrodons. If any trouble is experienced in this direction, the work should be turned over to a skilled radio man who will do the adjusting of the neutralizing capacities at little or no cost.

In the diagram on page 349 appears a typical neutrodyne receiver, in this case the Freed-Eisemann KD-50, which differs somewhat from the Freed-Eisemann NR-5 which is the factory-built set. It will be noted that this neutrodyne receiver has five tubes, consisting of two stages of radio-frequency amplification, followed by the detector, and then two stages of audio-frequency amplification. In the wiring diagram it will be noted that three neutroformers or specially designed radio-frequency transformers are used, together with three low dielectric loss variable condensers es-

pecially designed for use in connection with the neutroformers. Then there are two neutrodons, which are specially designed variable capacity neutralizing condensers with a maximum capacity of about 5 micro-micro-farads, or 0.000005 microfarad.

The neutroformers are represented by the inductance windings *AB* and *CDE*. The three variable condensers are represented by *FM*. The audio-frequency transformers are indicated by the windings *PB* and *GF*. Otherwise, the diagram is self-explanatory.

HOW TO SELECT GOOD INSTRUMENTS

When buying radio apparatus to construct a super-heterodyne, ultradyne, neutrodyne, or any other receiver, the following points should be looked for in order to ensure good results with the completed receiver. It is always advisable to purchase material from reliable manufacturers, although the price may be slightly higher, for only then can one have a good instrument, properly designed from the electrical and mechanical standpoints, and manufactured in a substantial and lasting manner. In all radio circuits the amount of energy received is extremely small and it is of prime importance to avoid losses, which stand for weaker signals or even no signals at all in the telephone receivers or loud-speaker. This is what happens when inferior or cheap instruments are employed, and that is the very reason why so many radio experimenters fail to obtain results with circuits which are known to be efficient.

THE VARIABLE CONDENSER TO SELECT

Let us start with variable condensers. These instruments should have bakelite or hard rubber insulation, and the plates should be of brass or aluminum

and rigidly assembled. The connection to the movable plates should be made by a good friction contact or a "pigtail" connection, which is a small piece of spring or wire joining the shaft and the binding post insuring a permanent and positive electrical connection, instead of having the delicate radio-frequency energy flow through the uncertain connection of the bearing. The shaft of the variable condenser should preferably be $\frac{1}{4}$ inch in diameter so that a standard knob and dial may be mounted directly on it. If a vernier arrangement is provided on the condenser itself, it should preferably be of the type moving the whole set of movable plates slowly rather than an extra plate, as this allows for an exact calibration of the instrument.

A non-vernier variable condenser may also be used with a vernier dial and knob; there are now on the market several efficient micrometer controls of a type which permits of exceedingly fine tuning.

The mechanical features of a variable condenser may be judged at sight. They are rigidity, proper fit of bearings, smooth but not a loose action, stiffness of the plates, proper action of the vernier, good tension adjustment, and the mounting and connecting provisions. Geared condensers are ideal for work requiring delicate capacity adjustment.

Aside from variable condensers, there are the fixed condensers of different kinds. Fixed condensers used as by-pass condensers need not be accurate, but should be tested on potentials up to 500 volts, especially in the case of the 1 microfarad paper condensers as well as the .006 microfarad mica condensers. Grid condensers, on the other hand, should be of high grade. Good grid leaks are also essential. The cheap combination grid leak and condenser should be looked upon with deep suspicion, for the best set may be ruined by the use of one of these cheap devices. Adjustable grid leaks are recommended in most circuits. The liquid

resistance grid leak, which has a liquid into which dip two electrodes, is ideal as a variable grid leak. Where definite capacities are recommended in the hook-up data, these capacities should be supplied.

VARIOMETERS, VARIO-COUPERS AND INDUCTANCES

Of variometers, there are many types and makes on the market, all intended for the same general purpose, namely, the variation of inductance over a range of 400 to 600 meters wave length, by means of the interaction of a fixed winding and a movable winding.

The mechanical features of a variometer are to be taken into consideration when considering the purchase of an instrument. The parts should be well made. The rotor or movable member should turn freely, yet the bearings should be free of loose play. There should be proper provision made for mounting the instrument. When it comes to the electrical considerations, the matter is somewhat more complex. Here it is a question of buying a reliable make of variometer, because an efficient instrument and a poor one may look very much the same. The best types have the smallest possible clearance between the two windings and are of a skeleton form, with a minimum of supporting material for the windings. Of course there should be good pigtail connections so as to eliminate the uncertain resistance of the bearing for passing current from the stator to the rotor and back again to the terminal. The same specifications apply to vario-couplers.

Inductances come in all shapes, sizes and types. Thus we have the compact inductance coils of the duo-lateral, honeycomb and other types. Here there is little to say with regard to the selection of the proper inductance, for all standard compact inductance coils are reliable and properly made. Where such compact

inductance coils are included in a receiving circuit hook-up, the size of the coil is usually indicated. Furthermore, the manufacturers of such coils furnish charts showing the inductance value and the wavelength of their different sized coils, together with the data for the condensers to be used with such coils.

When it comes to special inductances, it is a question



There is no more fascinating pastime than assembling a receiving set from parts. The work is simple—anyone can do it. And while the work progresses, the builder is steadily looking forward to the thrill of receiving the first signals with the product of his handiwork.

of the simple mechanical and electrical considerations. The inductance should consist of a durable support, such as bakelite tubing or stiff cardboard tubing, preferably the former. The winding should be tightly wound in place, so as not to unravel. It is preferable not to have such windings shellacked, as this tends to increase the capacity effect and reduces the effectiveness of the inductance.

POTENTIOMETERS AND RHEOSTATS

The potentiometer and rheostat bases should be made of heat-resisting and insulating material, or have a rugged metallic frame. The wire should be tightly wound so that it does not move when the sliding contact arm passes over it. It should run smoothly but at the same time insure good contact with the wire. Some carbon rheostats entirely enclosed in a porcelain base and working on the principle of applied pressure on a pile of carbon disks, are quite efficient and may be used to good advantage, although the fine adjustment they provide is not necessary with the more recent types of vacuum tubes.

Potentiometers, which are also called "voltage dividers," permit of fine variations of voltage to be obtained in circuits where accurate control is necessary. In most radio circuits the potentiometer is connected across the filament or "A" battery so that any value of voltage may be obtained within the limits of the battery. If contact were made directly to the cells of the battery, voltage variation would only be obtainable in steps of $1\frac{1}{2}$ or 2 volts, according to the types of battery used, while with the potentiometer, intermediate voltage values are available for control of various circuits. The potentiometer used with the usual radio-frequency receiver, the super-heterodyne and the ultra-dyne, should have a resistance of 300 to 400 ohms.

JACKS AND PLUGS

Jacks are merely automatic switches which change the connections of certain circuits when a plug is inserted between the blades. For instance, in the double-circuit jacks used in amplifiers, the transformer is disconnected and contacts are made with the telephones or loud-speaker when the plug is inserted between

the flexible blades. Some jacks are equipped with extra blades to light the filament of the vacuum tube when the plug is inserted. This latter type is called a filament-control jack. In selecting jacks for a given set, care should be used to see that the proper kinds of jacks are used, inasmuch as the jacks have different spring arrangements to regulate the handling of the specific circuits involved. Do not buy cheap jacks—this practice does not pay. In fact, jacks had best be omitted from a set unless the best can be obtained. At best, jacks are difficult to connect, especially with bus wire, and the springs sometimes are quite obviously as soft as lead. The jacks should be rigidly assembled and have micarta insulation. The small lugs to which the wires are soldered should be tinned so as to facilitate the soldering to the blades. The spring blades should be flexible and equipped with silver contacts. The frame, which is generally nickel-plated, should be of brass or bronze.

When it comes to plugs, the matter is largely a mechanical one. The plugs should be judged by their design and construction, with special regard to the ease with which connections may be made with the plug members. Some plugs have screw terminals to take the wire or telephone-tip connections, while others have quick-acting devices into which wires or telephone tips can be slipped and firmly held, only to be released by pressure on the releasing members, making the use of a screw-driver quite unnecessary.

AMPLIFYING TRANSFORMERS

Transformers, whether of the radio- or audio-frequency type, are primarily employed in radio receivers to amplify the signals received. The ratio of a transformer depends upon the number of turns in each winding. For instance, a transformer with a ratio of 3-to-1

has three times as many turns in the secondary winding as in the primary winding. The primary and secondary of a transformer are the input and output windings respectively. For audio-frequency amplification, transformers with low ratio, say 4:1 at the most, should be employed for good reproduction of the voice and music. Low-priced transformers should be regarded with suspicion. General appearances mean little, for a poorly constructed transformer may look just as good and even better than a first-class transformer.

THE PANEL

The panel should be of little importance to the working of a radio set. However, since the practice today is to run the live parts through the panel material, the builder must realize that the panel will be called upon not only to support, but to insulate the circuit as well. That is to say, a leaky panel may cause the set to fail entirely. There is no doubt in the mind of any experienced radio worker that the foremost panel materials are the laminated phenol condensation products, such as bakelite, condensite and so on, in the form of tough sheets which smell of carbolic when machined. The various qualities differ mostly in their finish and working properties. The higher grades when buffed by a conscientious polisher look like black plate glass and are certainly more desirable. Quarter inch thick material should be used if a large panel is called for. Some workers prefer to "grain" the panel, which consists in taking off the original polished surface by rubbing the panel its long way with pumice stone and oil.

Hard rubber panels, sold under the name of Radion panels, are excellent in so far as the electrical properties are concerned. Such panels are preferred by

some workers to the composition panels. Also, there seems to be a growing desire to build sets on plate glass panels, and the aid of a plate glass worker is usually sought to accomplish this, though it may be done by the careful amateur.

Aside from the panel, some of the apparatus of the usual receiving set is supported on a plain mounting board, which is fastened at the back of the panel. This plain wooden board takes the various accessories such as sockets, transformers, grid condenser and so on, while the panel takes the tuning units, switches, and rheostats. The terminals for antenna and ground as well as for batteries are placed either on the panel or, if the wiring is to be kept out of sight, on a strip of hard rubber or composition material, placed at the rear of the mounting board.

THE WIRING OF THE RECEIVING SET

The wiring of the usual receiving set should be done with care. It is not a mere question of connecting this binding post with that, but it is also a matter of running the wires as neatly as possible. Instead of using ordinary wire, which would be more or less limp and form a maze of wires, use is made of square silvered conductor, known as bus bar wire. The wiring plan should be carefully studied, and the builder should consider just how to place each conductor so as to make it as direct and neat as possible. Where flexible connections must be used, such as in making connection between taps of an inductance coil and switch contact points, flexible wire may be used when properly covered with flexible insulating sleeves known as "spaghetti."

The wire or bus bar should be bent at right angles when necessary. The exact place where the bend should be made can be found by trial. All the joints between

the wire or bus bar should, of course, be soldered, but care should be taken not to apply too much solder which is not only unsightly but introduces losses if not melted properly. Each connection fastened under a screw or nut should be made by bending the end of the wire or bus bar with a pair of roundnosed pliers to form a loop.

Check the wiring diagram as the wiring job progresses. Use a colored pencil to check off a given wire of the wiring diagram, as the corresponding wire is installed in the receiving set. After the entire wiring diagram has been checked off in colored pencil, the wiring job is completed. After the set is completely wired and checked once more, the builder should connect only the filament battery and try one tube in the various sockets to see if the filament lights properly. If the filament wiring is satisfactory, then one "B" battery may be connected and only one tube tried again in the various sockets, so that if by chance there should be a short circuit, only one tube would be burned out.

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